Attributes and consequences of health information systems data for antenatal care

Health status, health system performance and policy

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Thesis for the degree of Philosophiae Doctor (PhD)
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1 Scientific environment

The work for this PhD dissertation was performed at the Global Health Cluster, Division for Health Services, Norwegian Institute of Public Health, Oslo, Norway. The Department of Global Public Health and Primary Care and the Centre for Intervention Science in Maternal and Child health (CISMAC), Centre for International Health, Faculty of Medicine at the University of Bergen provided scientific support for the PhD.

The dissertation was completed as part of a larger research project – eRegistries for maternal and child health – led by the Norwegian Institute of Public Health, and implemented in collaboration with the National Institute of Public Health, Ramallah, Palestine and the World Health Organization, Occupied Palestinian territories.

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To my best friend, Kruthika: because without you, none of this would be possible.

3 Operational definitions

1. **Aggregated data:** consolidated data relating to multiple patients, and therefore unable to be traced back to a specific patient.[1]
2. **Antenatal care coverage:** proportion of women with a live birth in a given time period that received antenatal care four or more times.[2]
3. **Clinical algorithm:** a set of detailed, step-by-step instructions, which tell the user not only which task to perform but, in addition, the sequence in which they are to be performed.[3]
4. **Clinical guideline:** statements that include recommendations, intended to optimize patient care, and are informed by a systematic review of evidence and an assessment of the benefits and harms of alternative care options.[4]
5. **Digital health intervention:** a discrete functionality of the digital technology to achieve health sector objectives.[5]
6. **Effective coverage:** proportion of the population who need a service that receive it with sufficient quality for that service to be effective.[6] The term effective coverage is used in this dissertation to indicate quality-corrected coverage.[7,8]
7. **eRegistries:** electronic health information systems using communication technologies for the systematic longitudinal collection, storage, retrieval, analysis, and dissemination of uniform information on health determinants and outcomes of individual persons, to serve healthcare services, health surveillance, health education, knowledge and research.[9]
8. **Health management information systems:** a data collection system specifically designed to support planning, management, and decision making in health facilities and organizations.[10]
9. **Health system performance indicators:** indicators to measure one or more aspects of health system performance including, but not limited to, population health, health outcomes from treatment, clinical quality and the appropriateness of care, responsiveness, equity and productivity.[11]
10. **MCH eRegistry:** name of the electronic health registry currently being implemented for maternal and child health services in Palestine.[12]

11. **Patient registry:** an organized system that uses observational study methods to collect uniform data (clinical and other) to evaluate the specified outcomes for a population defined by a particular disease, condition, or exposure, and that serves one or more predetermined scientific, clinical, or policy purposes.[13] The term 'registry' is used to refer to both the act of recording or registering and to the record itself.[14]
12. **Quality of care:** the extent to which health care services provided to individuals and patient populations improve desired health outcomes. In order to achieve this, health care must be safe, effective, timely, efficient, equitable, and people-centered.[15]
13. **Quality of care for women and newborns:** the degree to which maternal and newborn health services (for individuals and populations) increase the likelihood of timely, appropriate care for the purpose of achieving desired outcomes that are both consistent with current professional knowledge and take into account the preferences and aspirations of individual women and their families.[15]
14. **Routine health information system:** a system that provides information at regular intervals of a year or less through mechanisms designed to meet predictable information needs. This includes paper-based or electronic health records, and facility- and district-level management information systems.[16]

4 List of abbreviations and acronyms

1. **ANC:** Antenatal care
2. **CI:** Confidence intervals
3. **CISMAC:** Centre for Intervention Science in Maternal and Child health
4. **DHS:** Demographic and Health Survey
5. **LiST:** Lives Saved Tool
6. **LMIC:** Low and middle-income countries
7. **MCH:** Maternal and child Health
8. **MDG:** Millennium Development Goal
9. **MICS:** Multiple Indicator Cluster Survey
10. **NGO:** Non-governmental organization
11. **PNIPH:** Palestinian National Institute of Public Health
12. **PRISM:** Performance of Routine Information Systems Management
13. **RHIS:** Routine health information system
14. **SARA:** Service Availability and Readiness Assessment
15. **SDG:** Sustainable Development Goal
16. **SFH:** Symphysis fundus height
17. **SPA:** Service Provision Assessments
18. **UNICEF:** United Nations International Children's Emergency Fund
19. **UNRWA:** United Nations Relief and Works Agency for Palestine Refugees in the Near East
20. **WHO:** World Health Organization

5 Summary

Background: A routine health information system (RHIS) serves as an important source of data for monitoring health of clients and health system performance. All countries use RHIS data for some form of priority setting; the extent of use varies across settings depending on the nature and availability of data. In the West Bank, Palestine, the paper-based routine health information system consisting of manually aggregated data is currently undergoing a transformation to an electronic health registry (eRegistry) consisting of individual-level data collected at the point-of-care for antenatal care services in primary healthcare.

Aim: The overall aim of the present study was to examine the consequences of the transformation from the existing RHIS based on manual aggregation, to an RHIS based on clinical records data for calculations of routine indicators and health system performance indicators. Various aspects of anticipated data-related changes were examined in the three papers constituting this PhD dissertation. In *paper I*, we calculated the routinely reported indicators from individual-level clinical data from antenatal paper records, and compared the values to the existing aggregate RHIS reports. In *paper II*, we calculated the coverage of at least one screening, coverage of appropriate number of screenings, and effective coverage of timely and appropriate screening of antenatal care interventions in public primary healthcare clinics, and explored selected infrastructure-related and maternal sociodemographic factors potentially associated with effective coverage. In *paper III*, we assessed the implications of using different available data sources in the health data ecosystem for modeling the scale up of antenatal care interventions in the Lives Saved Tool.

Materials and methods: Four data sources were used. First, manually aggregated RHIS reports submitted by care providers for primary healthcare clinics were retrieved (2015). Second, a cross-sectional study was conducted, where data were extracted from paper-based clinical records of women attending antenatal care (2015) from a random sample of public primary healthcare clinics. Third, secondary data were exported from the eRegistry electronic clinical records (2017). Fourth, data were obtained from the Palestinian multiple indicator cluster survey (2014). Using the

paper-based clinical records data, routinely reported indicators were calculated and compared to the aggregate RHIS reports (*paper I*). Data from paper-based clinical records were also used to generate coverage of clinical antenatal care interventions (*paper II*). All four sources of data were used to calculate distinct sets of values of input indicators in the Lives Saved Tool, and the mortality and morbidity averted through the scale-up of antenatal care interventions was modeled (*paper III*).

Results: *Paper I:* The values of the routinely reported indicators were significantly different when computed with clinical records data, compared to aggregate RHIS reports. The magnitude of the difference varied across indicators. There was divergence in the coverage of anemia screening between the clinical records data and aggregate RHIS reports.
Paper II: Effective coverage of antenatal care interventions was considerably lower than the coverage of at least one screening and coverage of the appropriate number of screenings for antenatal care interventions. Timely attendance at antenatal care in the clinics was low. Effective coverage of antenatal care interventions was higher in clinics with laboratory and ultrasound.
Paper III: All indicators required for input in the Lives Saved Tool could be calculated directly from the clinical records. The various sources of data yielded notably different results for the number of deaths averted. With clinical records data, the number of maternal deaths, stillbirths, and anemia cases that could be averted with the scale-up of health interventions were higher compared to the RHIS aggregate reports and the multiple indicator cluster survey. Each of the data sources also yielded varying compositions of antenatal care interventions averting deaths.

Conclusions: The transition from an RHIS based on manual aggregations to an RHIS based on individual-level clinical records data will lead to significant changes in the values of routinely-reported indicators, and the understanding of health system performance of antenatal care. Health systems managers should be aware of the underlying mechanisms of data-related changes.
Paper I: Reliable and complete routine indicators can be generated when clinical records data are directly used for automated computations. In such a system,

transcription errors involved in diagnosis and referral, and manual counting and application of indicator definitions are minimized, and the existing complex reporting structure can be circumvented.

Paper II: The metric used to quantify antenatal care service provision has consequences for the understanding of health system performance. Effective coverage of antenatal care interventions in public clinics can be increased by improving the provision of care according to recommended guidelines, including timely ANC attendance.

Paper III: The demonstrated variability in the Lives Saved Tool model output from using the various data sources highlights the importance of understanding the characteristics of data available in a health information system by program managers that use such planning tools for decision-making.

6 Summary in Arabic

المقدمة:

يعتبر نظام المعلومات الصحية الروتيني مصدر مهم للمعلومات اللازمة لمراقبة أداء النظام ومتابعة صحة مستخدميه بشكل مستمر. يتم حاليا في فلسطين وتحديدا في الضفة الغربية تحويل نظام المعلومات الصحية الورقية في عيادات رعاية الحمل والذي يتم فيه تجميع المعلومات يدويا إلى نظام إلكتروني يعتمد على تجميع المعلومات مباشرة على مستوى فردي , وذلك لحظة تلقي الرعاية الصحية المتعلقة برعاية الحمل.

هدف الدراسة:

الهدف العام لهذه الدراسة هوفحص تبعات التحويل من نظام المعلومات الورقية إلى نظام سجل إلكتروني يعتمد على تجميع المعلومات السريرية للأفراد (الحوامل) التي تستخدم بشكل مباشر لحساب المؤشرات الروتينية وتلك المتعلقة بأداء نظام المعلومات الصحية. تم فحص هذه التغيرات المرتبطة بالمعلومات من عدة نواح:أولا- حساب المؤشرات الروتينية, ثانيا- حساب زيارات التقصي للحوامل سواء زيارة واحدة على الأقل أو عدد مناسب من الزيارات,أو التغطية الفعالة لزيارات التقصي بناء على حضور الحامل في الموعد المناسب وتطبيق ملائم للتدخلات الصحية المتعلقة برعاية الحمل , ثالثا: تتضمن أثار استخدام مصادر مختلفة للبيانات المتاحة من اجل تعكيس تصميم وتحسين التداخلات من اجل للرعاية للسيدة الحامل ما قبل الولادة في برنامج انقاذ الحياة (Lives Saved Tool).

أدوات و طريقة البحث:

تم إستخدام أربع مصادر للمعلومات في هذه الدراسة: أولا: تم إجراء دراسة مقطعية لإستخراج المعلومات الموجودة في الملفات الورقية للحوامل المسجلات في عيادة رعاية صحة الام والطفل الحكومية لعام 2015 عن طريق إختيارعينة عشوائية. ثانيا: التقاريرالتجميعية المعدة يدويا من قبل مقدمي الرعاية الصحية لعام 2015. ثالثا: تم إستخراج معلومات ثانوية خاصة بالحوامل من سجل صحة الام والطفل الإلكتروني لعام 2017. رابعا: المسح المتعدد المؤشرات في دولة فلسطين 2014.

تم حساب المؤشرات الروتينية بإستخدام المعلومات السريرية الخاصة بملفات الحوامل ومقارنتها مع التقارير التجميعية المعدة يدويا. وقد تم إستخدام هذه المعلومات أيضا لإنشاء مؤشرات للتغطية الخاصة بالتدخلات الصحية المتعلقة برعاية الحمل. تم إستخدام هذه المصادرالاربعة للمعلومات لحساب قيم محددة للمؤشرات المدخلة في أداة إنقاذ الحياة ولحساب الوفيات والمراضة التي من الممكن تجنبها من خلال تطويرنموذج التدخلات الصحية المتعلقة برعاية الحمل.

النتائج:

-قيمة المؤشرات في التقارير التجميعية المعدة يدويا تختلف إحصائيا عند حسابها من المعلومات السريرية للحامل مقارنة مع التقارير الاحصائية التجميعية.كان هناك انحراف في معدل تغطية تقصي فقر الدم بين المعلومات السريرية والتقرير التجميعي, معدل التحويل لأسباب الخطر كان منخفضا في كل الظروف المتعلقة بصحة الام.

-قيمة التغطية الفعالة الخاصة بالتدخلات الصحية المتعلقة برعاية الحمل قليلة بشكل ملحوظ مقارنة بمعدل التغطية لزيارة تقصي واحدة على الاقل أوالتغطية لعدد مناسب من زيارات التقصي , كما أن حضور الحامل للعيادة في الموعد المحدد لزيارات التقصي كان منخفضا .معدل التغطية الفعالة لزيارات التقصي الخاصة بالتدخلات الصحية لرعاية الحامل كان أعلى في العيادات التي يتوافر فيها مختبر وفحص الموجات فوق الصوتية. ينما لم تظهر الخصائص الديموغرافية أي علاقة إحصائية مع التغطية الفعالة للزيارات.

-البيانات حسب السجلات المجمعة من العيادات، كعدد الوفيات للحوامل، و عدد الأجنة المتوفاه، وعدد السيادات اللاتي يعانين من فقر دم، أعلى من أعدادهن في نظام المعلومات الصحية الروتينية و مؤشرات المسح العنقودي (multiple indicator cluster survey) . كل ذلك يمكن تجنبه والحد منه مع التدخلات الصحية الموجودة وذلك اقتداء بإستخدام برنامج انقاذ الحياة (Lives Saved Tool) .وكل مصدر للبيانات أظهر اختلاف في التداخلات للرعاية الصحية لتجنب الوفيات.

الاستنتاج:

نقطة التحول من التقارير التجميعية المعدة يدويا إلى التقارير الصادرة عن المعلومات السريرية للحوامل سيؤدي إلى تغييرات مختلفة إحصائيا في قيمة المؤشرات وفي فهم أداء النظام الصحي المتعلقة برعاية الحمل.

يمكن إنشاء مؤشرات معتمدة ومكتملة بشكل افضل عند حسابها مباشرة وبشكل تلقائي من المعلومات السريرية, وذلك بشكل اساسي عن طريق تقليل الاخطاء الكتابية التي من الممكن حدوثها اثناء عمل التقارير التجميعية منها التشخيص والتحويل وأيضا أثناء الحساب اليدوي للمؤشرات أو عند تعريف المؤشر بحد ذاته.

هناك تبعات للمقياس المستخدم لقياس خدمات الرعاية الصحية في فهم أداء النظام الصحي المتعلق برعاية الحمل. حيث يمكن تحسين التغطية الفعالة الخاصة بالتدخلات الصحية المتعلقة برعاية الحمل في العيادات الحكومية من خلال تطوير الرعاية المقدمة حسب البروتوكول المعتمد حكوميا. مخططوا البرامج واستراتيجيات للنظام الصحي لا بد أن يفهموا ميزات المعلومات الموجودة في نظم المعلومات الصحية في عملية صنع القرار والاخذ بالاعتبار الاختلاف بين مخرجات أداة إنقاذ الحياة والمصادر الاخرى للمعلومات.

7 Original papers

This PhD dissertation is based on the following three papers:

Paper I

Venkateswaran M, Mørkrid K, Abu Khader K, Awwad T, Friberg IK, Ghanem B, Hijaz T, Frøen JF. **Comparing individual-level clinical data from antenatal records with routine health information systems indicators for antenatal care in the West Bank: A cross-sectional study.** *PloS one.* 2018;13:e0207813.

Paper II

Venkateswaran M, Bogale B, Abu Khader K, Awwad T, Friberg IK, Ghanem B, Hijaz T, Mørkrid K, Frøen JF. **Effective coverage of essential antenatal care interventions: A cross-sectional study of public primary healthcare clinics in the West Bank.** *PloS one.* 2019;14(2):e0212635.

Paper III

Friberg IK, Venkateswaran M, Ghanem B, Frøen JF. **Antenatal care data sources and their policy and planning implications: a Palestinian example using the Lives Saved Tool.** *BMC Public Health.* 2019;19(1):124.

8 Supporting publications from the overall project

The following papers from the larger research project provided the conceptual foundations and context to the PhD dissertation:

- **Venkateswaran M**, Mørkrid K, Ghanem B, Abbas E, Abuward I, Baniode M, Norheim OF, Frøen JF. **eRegQual—an electronic health registry with interactive checklists and clinical decision support for improving quality of antenatal care: study protocol for a cluster randomized trial**. *Trials* 2018;19:54.

- Flenady V, Wojcieszek AM, Fjeldheim I, Friberg IK, Nankabirwa V, Jani JV, Myhre S, Middleton P, Crowther C, Ellwood D, Tudehope D, Pattinson R, Ho J, Matthews J, Bermudez Ortega A, **Venkateswaran M**, Chou D, Say L, Mehl G, Frøen JF. **eRegistries: indicators for the WHO Essential Interventions for reproductive, maternal, newborn and child health**. *BMC Pregnancy and Childbirth* 2016;16:293.

- Frøen JF, Myhre SL, Frost MJ, Chou D, Mehl G, Say L, Cheng S, Fjeldheim I, Friberg IK, French S, Jani JV, Kaye J, Lewis J, Lunde A, Mørkrid K, Nankabirwa V, Nyanchoka L, Stone H, **Venkateswaran M**, Wojcieszek AM, Temmerman M, Flenady VJ. **eRegistries: Electronic registries for maternal and child health**. *BMC Pregnancy and Childbirth* 2016;16:1-15.

9 Introduction

9.1 Health information systems

A health system consists of several components and actors that provide a set of functions towards the delivery of health services to the population in order to improve people's health.[17] Several frameworks that characterize health systems have been put forth. According to the World Health Organization's (WHO) framework, a health system consists of six key components, also referred to as "building blocks", including 1) service delivery; 2) health workforce; 3) health information systems; 4) access to essential medicine; 5) financing; 6) leadership and governance.[17] A well-functioning health system composed of these building blocks intends to improve health, responsiveness and efficiency of services, while providing financial risk protection.[17] Some scholars have taken a critical view of the WHO "building blocks framework", citing its failure to account for the complexity and dynamicity of a health system.[18,19] Roberts et al (2008) proposed an alternative framework that accounts for the complex nature of health systems.[19] They defined "control knobs" of a health system consisting of financing, payment, organization, regulation and behavior.

While different frameworks for understanding a health system have divergent conceptual underpinnings, they all highlight the importance of routine data for health systems planning. Health information systems constitute a key building block in the WHO's framework,[17] and their cross-cutting role in the health system is acknowledged.[20]

Strengthening health information systems is an important aspect of establishing and maintaining strong health systems, and monitoring healthcare.[16,20] The availability of good quality and timely data is central to decision-making in public health. Data from health information systems are crucial for optimal planning and priority setting processes; the extent of use varies across settings and stakeholder types, and depends to a large extent on data quality and availability.

Several global initiatives have been established with the primary purpose of strengthening health information systems, such as MEASURE Evaluation[21] and the Health Metrics Network.[22] In 2010, the WHO director general called for collaborative efforts towards strengthening health information systems to enable countries to monitor progress in achieving better health.[23]

Data generated by a health information system needs to be scrutinized and improved for a health information system to fulfil its intended role of supporting, planning and monitoring a health system. A country health information system may encompass several sub-systems with distinct sources of data from population-based surveys, censuses, civil registrations and vital statistics, and from health-facilities. USAID's Demographic and health surveys (DHS)[24] and United Nations International Children's Emergency Fund's (UNICEF) Multiple Indicator Cluster Surveys (MICS)[25] are two examples of population-based household surveys. Health facility data can be derived from reports of the routine health information system (RHIS). Standardized tools such as the Service Provision Assessment (SPA)[26] and Service Availability and Readiness Assessment (SARA)[27] are also used to periodically gather data from a representative sample of health facilities to assess service provision in low- and middle-income countries (LMIC).

9.2 Routine health information systems

A RHIS constitutes an important part of any health information system. In many LMIC, RHIS data may be the only source of information immediately available to policy-makers.

Traditionally in LMIC, RHIS data are composed of a rather small and simplified set of indicators of aggregated data.[20] Conventionally, data availability in an RHIS has been shaped by the information needs of health systems managers for planning health services, and international donors for programmatic monitoring.

Primary data collections to support the information needs of a RHIS happen at places where care is provided, in health facilities and communities, with care providers undertaking the bulk of the data collections.[20,28] However in traditional RHIS, care

providers' and clients' information needs tend to receive little attention. At the same time, care providers often lack incentive and motivation to report good quality data, and have little appreciation of the information needs of health systems managers, much to the detriment of data quality.[28] Beyond the point of primary data collection, data in traditional RHIS are typically only available in aggregated form. The data aggregation happens first at the level of the health facilities, and then at district- and sub-national levels.

Many frameworks have been put forth for the development and evaluation of information systems.[29-31] The Performance of Routine Information Systems Management (PRISM) is a widely-used conceptual framework for data generation and data use in a RHIS.[32] In presenting this framework, Aqil et al (2009) discuss a "paradigm shift" in assessing country-level RHIS, moving beyond purely technical considerations of information systems to incorporate behavioral and organizational factors that affect a RHIS. According to the PRISM framework, a RHIS consists of several components – inputs, processes, outputs, outcomes and impact. Inputs consist of three factors: 1) technical factors of RHIS design and infrastructure; 2) organizational factors of RHIS governance; and 3) behavioral factors including competence and skills of personnel in data management.[32] The PRISM framework postulates that RHIS inputs impact processes, which in turn affect data quality and information use (output), ultimately influencing health system performance and health of populations (outcome).

The PRISM framework and accompanying tools[33] have been used in many LMIC such as Uganda, Pakistan, China, and Mexico,[32] to assess and improve various aspects of the RHIS. In general, these assessments produced fairly coherent, valid and actionable results.[32] Global initiatives such as MEASURE Evaluation and the Health Metrics Network have adopted the PRISM framework and tools for evaluations of RHIS,[33] further pointing to the framework's applicability in LMIC. Together with other data use frameworks, the PRISM framework forms the basis of a logic model for strengthening the use of health data in decision-making proposed by Nutley and Reynolds (2013).[34]

Processes of data collection, transmission, processing, and analysis are central to any RHIS.[20,32] The PRISM performance diagnostic tool[32,33] and the WHO data quality review toolkit[35] are instruments that can be used to support RHIS data quality assessments. The WHO data quality review toolkit suggests four dimensions for quality assessments of health facility data – completeness of data and timeliness of reporting, internal consistency, external consistency, and external comparisons of RHIS and population-based data.

Studies of RHIS data quality have assessed some or all of these dimensions of data quality. A literature search, conducted in 2018, revealed several issues that compromise data quality, with results primarily from sub-Saharan Africa. Regarding RHIS processes, identified problems included: inaccuracies in data transfer from one documentation source to another[36,37], selective over- or under-reporting[38-40] and errors in diagnosis and classification of conditions.[41-43] Technical factors affecting data quality were also identified by these studies, including the fact that excessive data were collected with no apparent use for calculating indicators in Tanzania,[38] Benin,[44] and South Africa.[45] A multi-country study assessing routine immunization data showed that data quality was negatively affected by complexity of reporting structures.[46] A separate data collection issue was the lack of consistent recording of numerators and denominators for calculations of indicators.[46] For example, when reporting health conditions or outcomes, it was the number of outcomes that were reported and not the number of clients with the outcome.[38] Behavioral factors affecting data quality identified by these studies included insufficient skills and training of care providers in RHIS tasks,[44,47,48] poor understanding of indicator calculations and definitions by care providers[49,50], and increased errors due to substantial burden of data collection in multiple records, registers and reports.[36] Insufficient feedback about the reported data was an important finding in many of these studies[50-52] possibly leading to low motivation of healthcare staff.

Digital health interventions, including electronic health information systems, have the potential to strengthen health information systems, and improve the quality, availability and accessibility of RHIS data.[53] The Global Action Plan has highlighted

"data and digital health" as one of the accelerators for the health-related Sustainable Development Goal (SDG 3: Ensure healthy lives and promote well-being for all at all ages).

More and more countries are adopting electronic RHIS. In settings with electronic health information systems, studies have shown improvements in timeliness of data,[39,54] and completeness of the RHIS reports.[54] But other issues such as over- or under-reporting of indicators[39,55] and data discordance between clinic registers and submitted electronic monthly reports[37,45] continue to prevail. In many implementations of electronic RHIS in LMIC, the overall structure of data-related processes of existing traditional RHIS is largely preserved – that is, data are first documented in clinical records, then transferred to clinic registers and finally submitted as electronic monthly reports.

The full potential of an electronic RHIS may not be achieved without paying due attention to workflow in health facilities during implementation. For example, a review of electronic health information systems in South Africa found that the number of indicators reported in the RHIS was still high with many of them perceived to be of no use, and that event counts were inaccurately entered into the electronic RHIS for indicator calculations.[45] Lind et al (2005) have highlighted a schism between those that design information systems and those that use the information derived from this data, such as district- and national decision-makers,[30,32] that could further hinder effective data use.

9.3 Maternal and child health information systems

Health information systems data and indicators are extensively collected and reported for maternal and child health in LMIC, both in the context of country-level monitoring and for international comparisons to assess global progress.[20,56,57]

An effective health information system should provide routine data on health status and health determinants, as well as health system performance.[10,20,58] Yet, data for comprehensive monitoring of health system performance are typically inadequate in many LMIC.[8] Kruk et al, in the Lancet Global Health Commission on high quality

health systems in the SDG era,[8] reported that fewer than half of the available indicators at country-level were measures of processes of care provision. The Commission calls for the collection and reporting of indicators that depict health system performance, and a RHIS that is geared towards capturing healthcare processes and outcomes.

Equity of healthcare was emphasized in the Countdown to 2015[56] and is an important aspect of the SDGs for global monitoring of maternal and child health.[59] Assessment of inequalities and inequities is an integral part of measurement of maternal and child health. Barros et al used survey data from 54 countries, and found that many settings with high overall coverage of maternal and child health services could still have significant health inequalities and inequities.[60] Much like with the availability of routine data for health system performance monitoring, inadequacies of health information systems in supporting monitoring of health equity have been pointed out.[61]

9.3.1 Maternal health indicators

Indicators for monitoring maternal health have been classified as those measuring inputs and processes, outputs, outcomes and impact[62] or grouped under the domains of mortality and health status, access to services, availability and utilization of services, service coverage, and quality of healthcare, as well as measures of governance and finance, and health workforce.[62,63]

Three main sources of data from health information systems in LMIC are commonly used to derive maternal health indicators: 1) population-based surveys such as DHS and MICS, which are the mainstay of country-level data in many LMIC; 2) health facility data from SPA or SARA; and 3) RHIS.

9.3.1.1 Monitoring maternal illness

The maternal mortality ratio was the indicator used to monitor impact of Millennium Development Goal 5 (MDG 5: improve maternal health). As more and more LMIC are achieving targets for maternal mortality reduction, there is an ever-increasing emphasis on addressing maternal morbidity.[64] Measuring maternal morbidity is an

important first step towards quantifying the burden of disease and addressing maternal health during the course of pregnancy and childbirth, and the overall quality of life of women afterwards.[65] Studies have pointed out the dearth of information on maternal morbidity estimates, with the available prevalence data probably only indicating the tip of the iceberg.[65,66] Traditional RHIS have limited data on maternal illnesses. A systematic review evaluating the availability of morbidity data in RHIS in South Africa noted that none of the identified studies were quantitative assessments and concluded that obtaining morbidity data using RHIS remains under-explored.[67]

Household surveys are less than ideal, if not unsuitable, for measuring most maternal morbidity indicators on a routine basis since they are intermittent, consist of client-reported data and suffer from recall bias leading to errors in classification of severity of disease. On the other hand, in settings with reasonable levels of healthcare provision and use, health facility data from antenatal care (ANC) and delivery should serve as an ideal source of data of maternal morbidity estimates.

The Maternal Morbidity Working Group, a technical working group established by the WHO, stresses the importance of creating and improving routine data collection systems that are geared towards monitoring maternal morbidity.[66] Purposeful strengthening of a RHIS can improve the quality and availability of routine data on maternal illnesses and usher monitoring of maternal illness into mainstream health data ecosystems.[68] Authors have argued for the use of RHIS data for outcome measurement of interventions of health systems, instead of establishing parallel program-based data collections.[68]

9.3.1.2 Monitoring antenatal care

ANC is a ubiquitous public health measure that consists of both preventive and curative strategies, with the overall aim of increasing the likelihood of better pregnancy outcomes for the mother and her baby.[69,70] In the continuum of care across reproductive, maternal, newborn and child health, ANC constitutes a key link.

The proportion of pregnant women having at least four visits with a trained health personnel during their pregnancy (ANC 4+) is almost universally used to assess

health system performance of ANC.[62] Several studies have pointed out the limited value of this indicator for monitoring health system performance, since it provides no information on the services received or the quality of care.[71,72]

Kruk et al recommend the use of effective coverage of ANC that captures if women have a timely first ANC visit and receive specific ANC interventions, to assess health system performance as opposed to only measuring ANC 4+.[8] The theoretical definition of effective coverage, as described by Shengelia et al (2005),[73] contains "quality", in addition to "utilization" and "need". Provision of quality healthcare is a core aspect of a well-functioning and effective health system.[8,74,75] Maximum health gain cannot be achieved if healthcare services are not of good quality.[73]

Conceptually, measuring quality of care involves appraising care provision against a particular standard.[76,77] Donabedian proposed measuring quality in terms of structure, process and outcomes, with the underlying premise that improvement in structure of care promotes optimal processes of care, which in turn results in better outcomes.[77] Good quality ANC is imperative to achieve the desired health outcomes for the mother and her baby.[57,78] Studies that have measured technical "quality" of ANC in the context of effective coverage of ANC and otherwise[6,72], have typically assessed ANC content, measuring if pregnant women were provided with all or a majority of services once during ANC.[6,79-81] Commonly reported measures of ANC content include a one-time measurement of weight and blood pressure, any urine and blood tests, iron-folate supplementation, tetanus immunization, counseling on pregnancy complications, and counseling for breastfeeding.[6,82,83]

As an alternative to measuring ANC content as the one-time provision of screening and counseling, processes of care measures derived from clinical ANC guidelines can be used.[84,85] Guidelines for clinical ANC interventions are reasonably well-defined and generally standard for pregnant women. The WHO provides normative guidelines of ANC, the latest being the 2016 WHO model for a positive pregnancy experience.[86,87] NICE[88] and ACOG[89] are two important sources of up-to-date clinical guidelines of care during pregnancy, based on the latest available evidence from effectiveness studies.

Guidelines for ANC interventions that are widely recommended are those that are supported by evidence of clinical effectiveness in improving health. Then, it is reasonable to assume that a measure of whether pregnant women receive complete clinical interventions at appropriate times during ANC better encapsulates service provision, compared to measuring if interventions were provided once during ANC. For example, the timely identification and management of preeclampsia requires repeated blood pressure measurements throughout pregnancy, as opposed to a one-time blood pressure measurement. However, guideline-based indicators are less commonly used in quality assessments of ANC, in comparison to certain other areas of healthcare, especially in LMIC.[84]

Most studies that have reported on ANC content and service provision have used household survey-data, or national or sub-national SPA or SARA, or combinations of the two data sources. In many LMIC where health service utilization tends to be sub-optimal, a household survey may be the only data source that provides a representative sample of the population. Given this, assessing if pregnant women get a set of healthcare services at least once during ANC is the most feasible metric to capture for "quality" assessments.[83,85] Such an approach, however, does not take into account the timing of ANC interventions received by pregnant women, how often they were provided, if the care provided was appropriate, or whether women were followed-up after screening with timely referrals or other managements. Household surveys that contain self-reported data from women are not suited to perform such comprehensive assessments of technical process of care. SPA and SARA can be used to assess some processes of care but only provide cross-sectional data at given points in time.

Health facility data from clinical records can be an alternative data source that can provide client-level information on the number, timing and results of screening and clinical examinations, and management information.

As with monitoring of inequities in coverage of any ANC visit or ANC4+ in the MDG era, monitoring inequities in coverage of ANC content and "quality" of services is getting attention to track progress towards SDGs.[8,90] The magnitude of

inequities in care provision was highlighted in a recent study of ANC in 91 countries, where wealthier women were much more likely to get blood pressure monitoring, urine and blood testing, and counselling during ANC, compared to poorer women.[90]

9.4 Data for maternal and child health priority setting

Health-related policy making is complex and depends on several factors, one of which is the availability of sound data. Shiffman and Smith (2007) described a framework for political priority of global health initiatives consisting of four important determinants – actor power, ideas, political contexts and issue characteristics.[91] Issues characteristics include the availability of credible indicators and a shared understanding of the severity of the health problem.[91]

As per the PRISM framework, information use is the output of a well-functioning RHIS. Despite the recognition of the importance of sound data for public health, accompanied by efforts and resources towards the strengthening of health information systems, many LMIC still lack health information systems that generate reliable and timely data that is relevant for local decision-making needs.[58,92] Strengthening health information systems not only involves improving data collection processes, but also enhancing the use of data by stakeholders including policy makers.[28]

Every data source within a health information system has its own share of strengths and limitations, and it is generally recognized that a health system benefits from a customized set of many data generation strategies, comprised of population-based and health facility data, to fulfil context-specific information needs. For example, household survey data provide representative estimates of populations, but surveys are typically conducted once in 4 or 5 years and have limitations in capturing content of care received, particularly for complex interventions.[93] Facility surveys provide an assessment of infrastructure in health facilities and the provision of services in a sample of health facilities, but are also intermittent. Aggregate RHIS data can provide routine information on health determinants and health outcomes, but may be unavailable or sometimes non-representative. Individual-level data from clinical records can provide longitudinal data on processes of care and delivery of interventions for direct calculation, but are not routinely available in most LMIC.

9.4.1 Lives Saved Tool

Modeling is valuable for public health program planning to evaluate effectiveness and cost-effectiveness of implementations.[94] In addition, models are useful when the outcome of interest is rare or difficult to measure, for example, maternal mortality ratio.[94] Among others, modeling has been used to evaluate vaccination programs, HIV/AIDS prevention and treatment programs,[95] infectious diseases control efforts,[96] and maternal and child health programs. The Goals model for HIV prevention and treatment programs,[97] the STDSim model for simulations of sexual relationship patterns among individuals with sexually transmitted diseases,[98] and the Lives Saved Tool (LiST) for maternal and child health[99] are some examples of modeling tools of health programs.

LiST has been extensively used globally, to guide priority setting processes in maternal and child health.[99-101] LiST is used to create population projections into the future, where the scale up of one or more interventions over a time period is modeled, and changes in numbers of maternal, neonatal and child deaths, and stillbirths are estimated. The structured outputs generated in LiST have been found to be intuitive for use by policy-makers.[102] Currently, LiST finds use in three broad arenas: 1) to inform global recommendations of interventions and the effectiveness of scale-up; 2) for strategic planning and priority-setting at the national level; and 3) to assess the impacts of ongoing large-scale implementations.[100]

Health status indicators, intervention effectiveness and baseline intervention coverage are the three primary inputs in LiST. Default proxies are used for baseline intervention coverage in LiST, considering the lack of actual coverage data in many settings. Coverage estimates are derived mainly from DHS and MICS. Facility surveys, research studies, and expert opinion have been used to configure default proxies in LiST. When available, RHIS data can be used to input health status and coverage indicators.

The quality and properties of data that are input in any modeling tool determines the output, and LiST is no exception.[103] As the availability, reliability and validity of data that are input in LiST improves, default proxies can be replaced with actual context-

specific data and indicators, and the usability and accuracy of the output in identifying priorities are likely to be enhanced.[104,105]

9.5 eRegistries

As described so far, traditional RHIS have gaps in capturing data for comprehensive maternal and child health monitoring and priority setting. The problem is not one of quantity of data collected at health facilities. Care providers typically document large volumes of client-related data during clinical care, although only a relatively small sub-fraction of these data is made available or used to report on aggregated indicators as part of traditional RHIS. If a health information system is designed to capture all the data collected at the point-of-care, these data can then be utilized to serve information needs of multiple different stakeholders.

eRegistries for maternal and child health are electronic health information systems that are purposefully designed to facilitate maximal data utilization downstream as well as upstream.[9] In an eRegistry, electronic data collection happens at the point-of-care at the individual client level. This single, unified source of data collected at the point-of-care can then be used to support multiple data-driven digital health interventions such as: clinical decision support, automated RHIS reporting, performance feedback dashboards for care providers, and SMS messages to clients.[9,106] The point-of-care data collection system allows for capturing vast amounts of data over time, which then allow for recombinations of data points to formulate a variety of types of indicators.

As part of the development of the eRegistries concept, a suite of indicators for the WHO essential interventions was developed to illustrate the type of data that could be collected in eRegistries.[85] The indicators are reflective of different components of each essential intervention, and consist of 4 broad types: 1) process indicators of screening; 2) outcome indicators of screening; 3) process indicators of management; and 4) outcome indicators of management.[85]

9.6 The West Bank – study context

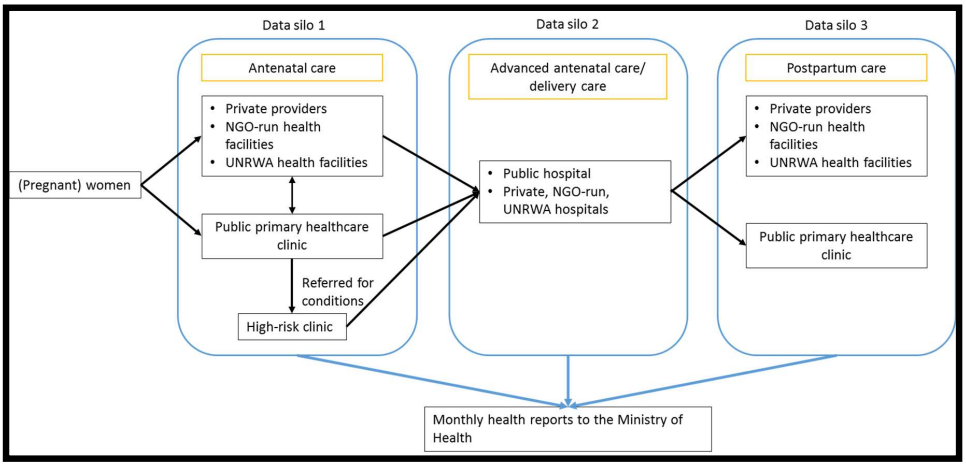
Data for this dissertation were collected from the West Bank, Palestine. The West Bank has a population of 4.5 million and a fertility rate of 4.3.[107] There are about 70,000 – 80,000 births per year in the West Bank, of which over 95% occur in health facilities.[107] The infant mortality rate was 11 per 1000 live births and the published stillbirth rate was 5 per 1000 births in the West Bank as of 2017.[107] The maternal mortality ratio in 2015 was 45.5 per 100,000 live births, according to UN estimates.[108] The Palestinian MICS 2014 reported that 95% of the women received ANC 4+.[109] Various reports have documented Caesarean section rates ranging from 14% to 25.8%.[107,110] According to a study from 2012, 2% of births were cases of maternal near-miss.[111]

The health system for maternal and child health consists of public, private, non-governmental organizations and the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA).[112] Health services in the public sector are organized as primary healthcare clinics and secondary health facilities. Public primary healthcare clinics provide antenatal and postpartum care, and newborn care including vaccinations. Labor and delivery services are only provided in secondary-level health facilities (hospitals). Every administrative district in the West Bank typically has one public hospital that caters to more than 80% of all the deliveries in that district, and several hospitals run by the private sector or by non-governmental organizations (NGO) catering to the rest of the population.[107]

As of 2018, there were 396 public primary healthcare clinics located throughout the West Bank, and more than 90% of these clinics provided ANC. Women in the West Bank have one designated primary healthcare clinic that is closest to their place of residence where they are supposed to seek antenatal, postpartum and newborn care (figure 1).[113] Pregnant women identified with certain conditions in primary healthcare clinics are referred to a high-risk (referral) clinic, to receive appropriate follow-up of the condition and continue with subsequent ANC. Women registered in public clinics may also seek care from private providers, as has been reported in other studies from

the West Bank.[114,115] No published literature exist on the exact patterns of use of the health system for ANC.

Figure 1: Flow of clients of antenatal care, delivery and postpartum care in the health system and data silos in the routine health information system in the West Bank, Palestine



Maternal and child health are high on the policy agenda and a priority area for the Palestinian health system.[116] In the Lancet commentary "Health in the Occupied Palestinian Territory", Mataria and colleagues call for revitalized efforts to strengthen the health system in Palestine along the lines of the WHO health system building blocks.[117] The authors call for strengthening of primary healthcare in general and the health information system in particular. The importance of robust health information systems is reiterated in the article on maternal and child health in Palestine, where the authors point out the need for routine data on context-specific prevalence and service delivery to inform resource allocation in an already fragile health system setting.[116] The general scarcity of data on maternal morbidities in the Palestinian setting is also recognized.[118]

9.6.1 The existing health information system

Until the second half of 2016, the RHIS for primary healthcare in the West Bank was paper-based. Aggregate reports of event counts were manually prepared by the care providers and submitted every month from each primary healthcare clinic (figure 1). For ANC, all clinics were obliged to report on a set of predefined indicators to the Ministry of Health (box 1).

Box 1. List of indicators from antenatal care available in the existing routine health information system

Published

1. Antenatal visits to the primary healthcare clinics by district:
   - 1.1. Number of pregnant women registered for antenatal care
   - 1.2. Total number of antenatal visits
   - 1.3. Rate of visits per pregnant woman[1]
   - 1.4. Coverage of antenatal care in public primary healthcare clinics[2]
   - 1.5. Distribution of new registered pregnant women according to age (<16, 16-40, >40)
2. Iron and folic acid supplementation by district
   - 2.1. Number of folic acid tablets distributed
   - 2.2. Number of iron and folic acid tablets distributed
   - 2.3. Rate of folic acid and iron per pregnant woman
3. Referrals of high-risk pregnancies
   - 3.1. Number of pregnant women referred by age group
   - 3.2. Percentage of referrals among all registered pregnant women
   - 3.3. Number of women referred for: gestational diabetes mellitus, multiple pregnancy, malpresentation at term, recurrent miscarriage, pre-eclampsia, rhesus negative blood group, fundal height discrepancy, history of Cesarean section, oligohydramnios, polyhydramnios, bleeding during pregnancy, premature rupture of membranes, others
4. Anemia among pregnant women by district:
   - 4.1. Total number of hemoglobin tests at 36 weeks
   - 4.2. Number of tests of Hemoglobin <7 g/dl among total hemoglobin tests
   - 4.3. Number of tests of Hemoglobin 7 – 9 g/dl among total hemoglobin tests
   - 4.4. Number of tests of Hemoglobin 9 – 11 g/dl among total hemoglobin tests
   - 4.5. Percentage of mild, moderate and severe anemia[4]

Not published

1. Number of women referred to hospitals for delivery or antenatal complications
2. Number of pregnant women examined by doctor, nurse:
3. Number of miscarriages among all registered pregnant women
4. Number of home visits (if any)

Calculations of proportion indicators (done centrally at the Ministry of Health)

[1] Total number of antenatal visits/ Number of pregnant women registered for antenatal care

[2] Number of pregnant women registered for antenatal care/total number of births by district

[3] Number of positive tests/total number of blood sugar tests

[4] Number of hemoglobin test results indicating anemia/total number of hemoglobin tests

A description of the RHIS processes and RHIS determinants of the paper-based RHIS in the West Bank, along the lines of the PRISM framework, is provided below.

9.6.1.1 RHIS processes

In the paper-based RHIS, care providers in primary healthcare clinics used paper-based, structured clinical records (appendix 1) for documentations of clinical care during ANC.[113] According to standard practice, a clinical record was opened for each woman at registration of her pregnancy at the clinic. Two clinic registers – one for general ANC and one for antenatal ultrasounds – were used for reporting purposes. From the paper-based clinical records, care providers (typically nurses) manually counted and copied specific information needed for monthly reports into clinic registers at the end of each workday or in some cases, once a week. Information from the clinic registers was then summarized into counts and written on the RHIS reporting forms.

All clinics submitted reports of indicators of ANC, postpartum and newborn care, while referral (high-risk) clinics additionally reported on maternal conditions from the referrals received from primary healthcare clinics (figure 1).

The monthly reports were first submitted to the district-level supervisors of maternal and child health services, who checked the reports for completeness and subsequently sent the reports to district health authorities. At this stage, the reports were computerized by a data entry clerk at the district health offices and sent to the Ministry of Health and Bureau of Statistics.

A few of the event counts were converted to proportion indicators centrally at the bureau of statistics. Most of the routinely reported indicators from the clinics were published by the Palestinian Ministry of Health once a year (box 1).

Although hospitals may provide ANC services for pregnant women, they are not obliged to report on any data regarding ANC to the RHIS. However, all health facilities providing labor and delivery services, private and public, are obliged to report on maternal deaths and the number of deliveries, stillbirths and neonatal deaths disaggregated by sex.

9.6.1.2 RHIS determinants

RHIS reporting from ANC followed a complex structure consisting of separate data flows from primary healthcare clinics and high-risk clinics (for maternal conditions from referrals) for the same population of pregnant women. It was unclear if the high-risk clinics reported on one or more maternal condition for each pregnant woman referred.

Care providers in the clinics typically consist of nurses, midwives and non-nurse/midwife health workers, who are involved with the bulk of health data collection and preparation of RHIS reports. Doctors usually visit clinics once or twice a week and perform clinical examinations and antenatal ultrasounds. As per protocol, district-level supervisors were supposed to visit all clinics once a month. During such visits, supervisors were required to check five randomly selected clinical records for completeness, assess accuracy of data transfer from the clinical records to the clinic registers and subsequently provide feedback to the nurses in the clinics. In reality (from expert opinion of the study team in the West Bank), supervisory visits were erratic and the exact content of feedback was often unclear.

Care providers reportedly spent a significant portion of their time in repetitive documentation of health data in clinical records, registers and monthly reports, which may have had an impact on the RHIS data quality.

From the start of the project in 2014 and through 2018, no published studies of assessments of RHIS data quality were identified from the West Bank.

9.6.2 Transformation of the routine health information system

9.6.2.1 Implementation of an electronic maternal and child health registry

The health authorities of Palestine made the decision to implement a national electronic maternal and child health registry (MCH eRegistry, named after the parent global initiative) as a measure towards strengthening and modernizing the RHIS in primary healthcare. As a result, the paper-based RHIS, providing only aggregated data, is currently transitioning to an electronic health registry consisting of individual-

level data collected at the point-of-care for ANC services.[113] The transition started in late 2016 and was ongoing as of 2019.

At the outset, this implementation was targeted towards improving RHIS input, optimizing RHIS processes and minimizing duplicative documentation efforts of care providers. In the long term, the intention of the Palestinian Ministry of Health is to enhance the use of data at all levels of the health system by different maternal and child health stakeholders.[9]

The planning phase of the implementation started in 2014. The initial stage was devoted to design and software customization of the MCH eRegistry.[113] A national multidisciplinary stakeholder group composed of doctors and nurses providing maternal and child health services, midwives, district health supervisors, Ministry of Health staff, and representatives from NGO-run health facilities was established.

ANC services were the first to be included in the implementation. Care providers of maternal and child health services directly enter clinical data during client care into electronic checklists; checklists are identical in structure and content to the paper-based clinical records.[9,113] As of 2018, the MCH eRegistry supported two digital health interventions driven by the clinical data entered at the point-of-care in the clinics – 1) individualized clinical decision support based on guidelines for care; and 2) automated generation of RHIS reports, where the manually aggregated and reported indicators are now generated electronically every month, using the clinical data entered into the MCH eRegistry for each primary healthcare clinic.

Both of the abovementioned digital health interventions were formulated in collaboration with the stakeholder group. Specific nationally recommended clinical interventions pertaining to antenatal, postpartum and newborn care were identified and their corresponding national guidelines were gathered. Algorithms for clinical care were drafted based on the available guidelines for each of the interventions and then discussed in two stakeholder seminars to ascertain if they reflected national recommendations and clinical practice. Clinical algorithms based on the final set of agreed guidelines were then used to build the clinical decision support functionality in the MCH eRegistry.[113]

Primary healthcare clinics in the West Bank have been provided with desktop computers and an internet connection, and the care providers have access to the MCH eRegistry through a web browser. The Palestinian MCH eRegistry is hosted in the DHIS2 software platform.[119]

9.6.2.2 Mechanisms of change

Table 1 shows the mechanisms by which the introduction of the MCH eRegistry in primary healthcare clinics will modify the existing landscape of RHIS processes, as identified for this dissertation. In the short term, the implementation of the MCH eRegistry acts as a technical determinant of RHIS that would lead to modifications in data collection, processing, transmission and analysis.

Table 1: Summary of expected changes to RHIS processes and outputs with the transformation from the manual, paper-based RHIS to the MCH eRegistry

RHIS processes	*Characteristics*	
	Existing RHIS	Transformed RHIS
1. Data collection	1.1 Documentation of clinical datapoints on paper-based antenatal records at point-of-care 1.2 Manual diagnosis and classification of maternal conditions 1.3 Data entry into ledgers/registers 1.4 Summarize counts for indicators and prepare reports 1.5 Reports sent to district health supervisors	Documentation of clinical datapoints in electronic antenatal records at point-of-care
2. Data transmission	2.1 Primary healthcare clinics report on all indicators except for maternal conditions 2.2 High-risk (referral) clinics report on maternal conditions from referrals	Automated electronic reports of all health and health system indicators from primary healthcare clinics
3. Data processing	3.1 Paper reports of event counts (submitted by care providers) computerized by data entry staff 3.2 Denominators and definitions applied at the national level for some indicators	Definitions for indicators applied to clinical datapoints at the individual-level with a single denominator (total number of registered clients)
4. Data analysis	Limited usable/available data for health system performance monitoring	Data available on content of care, frequency, timing of health interventions during antenatal care

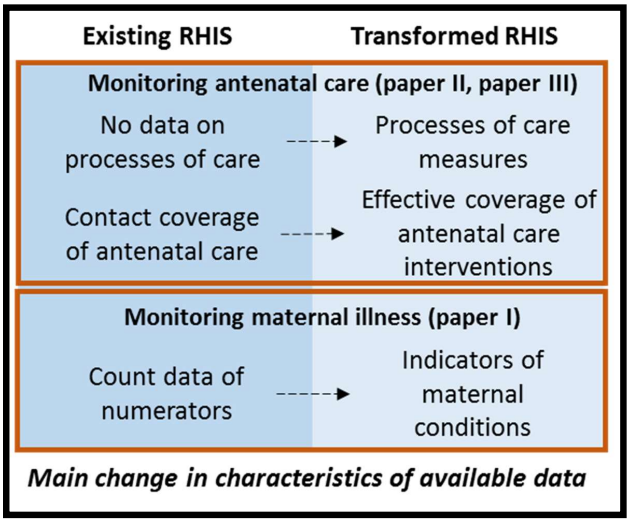
RHIS: Routine health information system
MCH: Maternal and child health

9.7 Rationale for dissertation

The expected changes in the data-related processes, as a result of the transition from an RHIS based on manual aggregations to an electronic health registry, may lead to significant changes in the values of all health and health systems indicators. Such potential shifts of data could be disruptive to the health system if not anticipated and understood by health systems owners, managers, and care providers, as they may base their planning and policies on such data. This dissertation, therefore, includes an assessment of the characteristics of change in health- and health system performance indicators, as outlined in the mechanism of change, with the goal of preparing the health system for modified understanding that might emerge.

Figure 2 shows the focus areas of the papers that constitute this dissertation, where different aspects of the mechanism of change were evaluated through indicators of health status and health system performance.

Figure 2: Main characteristics of changes expected to occur with the transition of the RHIS investigated in the papers in this dissertation



10 Study objectives

10.1 Hypothesis

Transition from an RHIS based on manual aggregations to an RHIS based on individual-level data will lead to significant changes in the values of routinely-reported indicators and interpretations of health system performance of ANC.

10.2 Research questions

1. How will the change from the existing RHIS based on manual aggregation, to individual-level data from clinical records, affect values of routinely reported ANC indicators in the public clinics?
2. How will the change from contact coverage reports in the existing data ecosystems, to effective coverage indicators for ANC interventions from individual-level data, affect measures of health system performance of ANC in the public clinics?
3. How will the outputs from the Lives Saved Tool be affected by using different sources – aggregate RHIS reports, individual-level data from clinical records and population-based survey data?

10.3 Aim

To assess the consequences of using individual-level clinical data to generate health- and health system performance indicators, compared to data from a household survey and the existing aggregated RHIS.

10.4 Objectives

The specific objectives of this dissertation are to:

1. Calculate routinely reported indicators from individual-level clinical data from antenatal paper records, mimicking an eRegistry, and compare these with indicators reported in the existing RHIS in the West Bank (*paper I*).

2. Calculate coverage of at least one screening, appropriate number of screenings of ANC interventions, and effective coverage of ANC interventions in public primary healthcare clinics in the West Bank, Palestine, and explore selected infrastructure-related and maternal sociodemographic factors potentially associated with effective coverage (*paper II*).

3. Assess the implications of using different available data sources in Palestine – routine data, a population-based survey, extracted paper-based records and the eRegistry – when used for modeling the scale up of ANC interventions in the Lives Saved Tool (LiST) (*paper III*).

11 Materials and methods

11.1 Setting and design

The overall implementation of the MCH eRegistry and the resultant RHIS transformation were operationalized as a combined research-implementation initiative.

The study area from which data were collected for this dissertation consisted of five districts in the West Bank, namely, Bethlehem, Jenin, Nablus, Ramallah/Al-Bireh and Salfit (figure 3).[113] In total, there were about 32,000 births per year in these five districts, constituting almost 50% of all the births reported annually in the West Bank.[107] Out of the 180 clinics in these districts that were run by or reported to the Palestinian Ministry of Health, 165 clinics that offered routine ANC services were included in the first phase of the implementation. These 165 clinics enrolled 11,416 new pregnancies in 2014 (the number of new registrations of pregnancy per clinic was available from a facility inventory checklist described in section 11.2.1), an average of 70 pregnancies per clinic per year. There were nine high-risk (referral) clinics operating in the five districts.

A subsample of the 165 phase 1 clinics was included in the cross-sectional study presented in this dissertation (described in section 11.2.2).

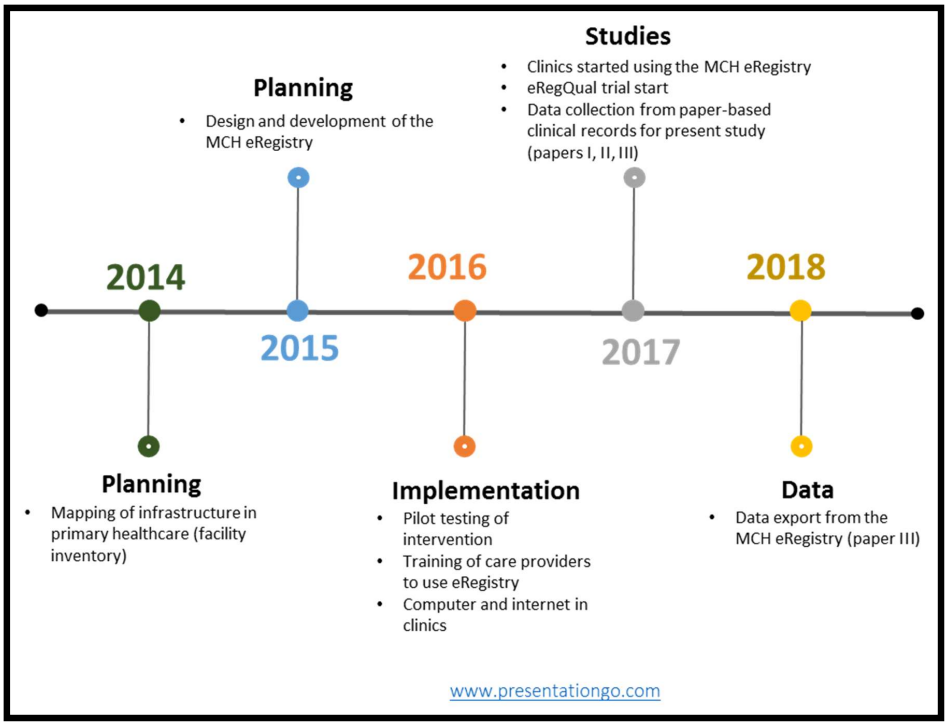
A cluster-randomized controlled trial (the eRegQual study) was embedded in the phased national implementation of the MCH eRegistry.[113] Clinics included in the eRegQual study and randomized to the intervention arm received the eRegistry for ANC, and the control clinics continued to operate with paper-based clinical records throughout the period of the trial.[113] The eRegQual study started recruitment in January 2017. After completion of the follow-up period in July 2018, the control clinics were included as part of the eRegistry implementation.

Figure 3: map of the West Bank with the five districts constituting the study area encircled

11.2 Data collection and data sources

All activities related to data collection were conducted in close collaboration with the field coordinators of the study at the Palestinian National Institute of Public Health (PNIPH), WHO, Palestine.[12] Figure 4 shows the specific timing of the data collections for the papers constituting this dissertation, in relation to the timeline of the overall project and the eRegQual trial between 2014 and 2018.[113]

Figure 4: Project plan indicating timing of data collections for the papers constituting this dissertation



11.2.1 Facility inventory

An assessment of all primary healthcare clinics in Palestine using a facility checklist was conducted in 2014, as a first step towards the national implementation of the MCH eRegistry/eRegQual trial (figure 4).[113] The list of data elements collected in the facility checklist (box 2) was prepared jointly by the researchers and the country

implementation team. The PNIPH coordinated the data collection, while the district health supervisors facilitated the process. Midwives or nurses from each clinic completed the assessment form and returned them to the district supervisors, who then checked the information for completeness and forwarded them to the PNIPH. Project staff at PNIPH computerized the completed forms. The researchers checked all the data for accuracy and completeness for every clinic and requested clarifications or additional information from the clinics, where needed. Specific data from the facility checklist were used for the following purposes in this dissertation:

- Referral patterns of primary healthcare clinics: to understand flow of health information in primary healthcare (*papers I, II, III*).
- Number of new pregnancies registered in each clinic over one year in 2014: sampling and sample size estimations for data collection from paper-based clinical antenatal records (described below) (*papers I, II, III*).
- Information related to clinic infrastructure: to understand availability of service, staffing and care provision in the clinics (*paper II*).

Box 2. List of information collected in the facility inventory checklist

Clinic infrastructure
Types of MCH service provided
Computer availability
Internet connectivity
Days of operation
Number of rooms used to provide MCH services
Availability of beds, measuring tapes, sphygmomanometers
Laboratory and ultrasound availability
Human resources
Number of doctors, nurses, midwives, specialists and non-nurse/midwife health workers
Number of full-time and part-time staff positions
Client-related
Number of new pregnancies registered over one year (in 2014)
Number of total pregnancies handled by the clinic over one year
Number of primigravidae
Number of pregnant women<16 years and >40 years
Health system mapping
Place of referral of high-risk pregnancies
Place of referral for laboratory and ultrasound examinations
Place of referral for secondary and tertiary MCH care
Place of referral for deliveries of pregnant women

11.2.2 Paper-based clinical records

Data were collected from paper-based clinical records for ANC of all pregnancies registered in 2015 in a cross-sectional sample of primary healthcare clinics. Paper-based clinical records were the source of individual-level data in the clinics in the existing RHIS. Paper-based clinical records were printed centrally at the Ministry of Health and distributed to all clinics. One clinical record was opened for each woman at the time of registration for ANC. The clinical record (appendix 1) consisted of the following sections of documentation:

i. *Background sociodemographic information:* mother's name, age, date of birth, address, phone number, age at marriage, age at first pregnancy, number of years of education
ii. *Current pregnancy*: last menstrual period, expected date of delivery, gestational age at pregnancy registration, obstetric score (gravida, parity, number of living children and number of abortions)
iii. *Obstetric history*: consecutive abortions, perinatal deaths, Caesarean sections, birth complications during previous deliveries
iv. *Medical and family history*: diabetes mellitus, hypertension, renal and heart disease
v. *Clinical examinations*: height, weight, blood pressure, symphysis fundus height, presentation, edema
vi. *Laboratory tests*: blood group and Rh type, hemoglobin, blood sugar
vii. *Ultrasound examination*: placenta, presentation, amniotic fluid index, estimated fetal weight, expected date of delivery, fetal growth parameters
viii. *Managements*: tetanus toxoid immunization, iron-folate supplementation
ix. *Complications warranting referrals*: gestational diabetes mellitus, pre-eclampsia, anemia (hb <9.5 g/dl), discrepancy between fundal height and gestational age, oligo- or polyhydramnios, malpresentation at term, multiple pregnancy, preterm/premature rupture of membranes, Rh negative blood group and multiple pregnancy

11.2.3 Aggregate RHIS reports

Aggregate RHIS reports of event counts of all the indicators submitted by the care providers were obtained for: 1) the primary healthcare clinics included in the data collection of the paper-based clinical antenatal records (RHIS clinic reports); 2) the corresponding high-risk clinics reporting at the district-level (RHIS district reports); and 3) the national level reports for ANC for the West Bank (nationally reported statistics for the 5 districts) (table 2). Aggregate RHIS reports per clinic were obtained as electronic spreadsheets from the Ministry of Health for 2015.

RHIS clinic reports contained the following three indicators: maternal age, antenatal visits and anemia at 36 weeks. RHIS district reports contained event counts of maternal conditions from referrals. RHIS national statistics included all routinely reported indicators. In the national reports, all indicators were published as event counts except anemia at 36 weeks published as a proportion (hemoglobin tests with value <11 g/dl/ hemoglobin tests reported).

Table 2: Aggregate RHIS reports from different organizational hierarchies of the RHIS and the denominators used to transform event counts to proportion indicators

Aggregate RHIS reports	Denominator for computing indicators out of event counts
RHIS clinic reports	Number of pregnancies enrolled, as reported by care providers (n=1463)
RHIS district reports	Pregnancies enrolled in clinics included in phase 1 of implementation (n=11,416)
Nationally reported statistics	Pregnancies enrolled in all clinics in the 5 districts (n=14,544)

RHIS: Routine health information system

11.2.4 eRegistry electronic clinical records

A total of 76 primary healthcare clinics in the 5 districts started using the MCH eRegistry during the second half of 2016 (figure 4).[113] Use of the MCH eRegistry is mandatory for all clinics, and all paper-based clinical antenatal records were removed

from the clinics during the time of the implementation, to secure full adherence to the use of the eRegistry for all clinical documentations.

The eRegistry electronic clinical records were identical to the paper-based clinical records in terms of the datapoints collected. The main distinction between paper-based clinical records and the eRegistry electronic clinical records is the way in which details of clinical management are captured in the two systems. Clinical decision support and referral recommendations are part of the functionalities of the eRegistry, triggered by the data that are entered into the electronic records at the point-of-care by the care providers. Subsequently, care providers are prompted to indicate if the recommended actions suggested by guideline-based clinical decision support are performed or not.

11.2.5 Multiple indicator Cluster survey

MICS is a household survey that is conducted once in 4 years in Palestine.[109] The latest available MICS was conducted in 2014, when 13,367 women from the West Bank and Gaza were interviewed. Twenty-two per cent of the women (n=2940) included in MICS 2014 had at least one live birth in the 2 years prior to the survey.[109]

11.3 Sample

11.3.1 Sample size

We made sample size estimations for data collection from paper-based clinical records to report on two sets of outcomes – indicators of health status (routinely reported indicators including maternal conditions) and indicators of health system performance (coverage of ANC interventions).

Sample size was determined to enable the detection of a frequency of maternal condition of 1% (margin of error of 0.5%), and a coverage of ANC interventions of 40-60% (margin of error of 2-3%). Severe anemia, with a frequency of 1% in this setting, is an example of a maternal condition that was important and feasible to capture in this data collection[120]. No reports on care provision in primary healthcare were available in published literature; coverage of ANC interventions for sample size calculations were based on best available knowledge.

To enable capture of these outcomes in a study population of 11,400 pregnancies, a sample of 1344 pregnancies was required. Sample size was calculated with the software 'OpenEpi', using the following formula:[121]

Sample size n = $\mathbf{[Np\ (1-p)]/\ [(d^2/Z^2_{1-\alpha/2}*(N-1)\ +\ p*(1-p)]}$, where N is the finite population correction, p is the % frequency of outcome, d is the margin of error.

11.3.2 Sampling

The main goal of the sampling was to obtain a dataset of pregnancies that was representative of the healthcare received by pregnant women in the public health system in the West Bank. In order to avoid selecting a non-representative sample of small clinics that catered to fewer pregnant women, a random sample of primary healthcare clinics was selected by probability proportional-to-size sampling. Selection was continued until a certain number of clinics was available to achieve the required sample of pregnancies, on condition that data were extracted from paper-based clinical records of all pregnancies registered for one year in 2015 in the selected clinics. There were no inclusion or exclusion criteria based on individual pregnancies and all clinical records were included in the data collection.

Given that clinics were selected with unequal probability sampling, inverse probability sample weights were added such that pregnancies from smaller clinics were assigned higher weights than pregnancies from larger clinics. This would provide data from clinical records that were comparable to RHIS aggregate reports, produce indicators with robust standard errors, and provide results with more generalizability to the five districts from which the sample was selected.[122]

Seventeen primary healthcare clinics were included in the cross-sectional study of paper-based clinical records. Data from clinical records were available for 1369 pregnancies.

Clinic-level and individual-level sample characteristics are summarized in table 3.

Table 3: Sample characteristics of clinics and pregnancies included in the cross-sectional study of paper-based clinical antenatal records

Characteristics	Number
Laboratory and ultrasound	Number of clinics (number of pregnancies)
• Both	6 (n= 631)
• Only laboratory	2 (n= 134)
• Only ultrasound	2 (n= 138)
• Neither	7 (n= 466)
Age of women (years)	Number of pregnancies
• <20	222
• 21-35	1029
• >35	118
Education of women (years)	
• <10	149
• 10-13	591
• >13	514
Age of women at marriage (years)	
• <20	695
• >20	573
Parity	
• Nulliparous	501
• Multiparous (less than 4)	666
• Multiparous (more than 4)	186

11.4 Data extraction

Data were extracted from paper-based clinical records by two nurse midwives trained in data extraction. Data collection forms were set up in the DHIS2 software;[119] the structure and content of the data collection forms matched the paper-based clinical records. Data entry staff conducted the extraction between January and April 2017 (figure 4). Data from about 10% of all the clinical records (n=133) were entered twice – once by each of the data entry staff.[113] The double-entered data were checked by the field coordinators for consistency. Any deviations in the two sets of entered data were solved through discussions between the field coordinators and the data entry staff. In case of persisting disagreements, one of the field coordinators made the final judgement.

Secondary data for analyses were exported from the eRegistry electronic clinical records. Data on all pregnancies registered on or after 1st of January 2017 and passed 44 weeks of gestation as of 30th of April 2018 were included. There were no inclusion or exclusion criteria based on individual characteristics.

We obtained the dataset of the 2014 MICS in Palestine, on request from the country MICS team. We only used data for the West Bank (55% of the survey sample, n=1609) available in MICS 2014.[109]

11.5 Indicators

Distinct sets of predefined indicators are presented in each of the original papers that constitute this dissertation. We identified all routinely available indicators in the existing health data ecosystem comprised of the existing aggregate RHIS and MICS. In addition, national guidelines for ANC were identified and used to define indicators of health system performance of ANC.

11.5.1 Routine health information system indicators (paper I)

We included indicators that were part of the existing RHIS (described in 9.6.1, box 1), reported from primary healthcare clinics that could also be calculated using clinical records data. The included indicators are listed below:[123]

- Mean number of ANC visits
- Maternal age
- Anemia: maternal anemia at 36 weeks
- Reportable maternal conditions (from referrals):
    - Gestational diabetes mellitus
    - Multiple pregnancy
    - Malpresentation at term
    - Recurrent miscarriage
    - Preeclampsia
    - History of Cesarean sections
    - Anemia: at any gestational age
    - Rhesus negative blood group

- Fundal height discrepancy
- Oligohydramnios or polyhydramnios

The following indicators that were part of the aggregate RHIS reporting from primary healthcare clinics were excluded: 1) iron-folate supplementation that was reported as the number of units prescribed (box 2) and data for RHIS reporting were not derived from the clinical records per se; and 2) two maternal conditions – preterm rupture of membranes and antepartum vaginal bleeding, for which women were likely to be immediately referred from primary healthcare for emergency obstetric care to a secondary health facility, and as a result, documentation of data required to calculate these indicators in the clinical records may be incomplete.

The health system-prescribed definition of each indicator meant to be used for manual aggregation while preparing monthly reports of event counts in the existing RHIS was documented. We used clinical datapoints from the paper-based clinical records, applied the definition of each indicator and reconstituted the selected indicators. For all the reportable maternal conditions, we calculated the value of the indicator as any occurrence of the maternal condition and then, including only those with the condition and referred, as is the reporting practice in the existing aggregate paper-based RHIS. Event counts of the aggregate RHIS reports of the same selected indicators were transformed to proportions using the predefined denominators (described in section 11.2.3).

Calculated values of indicators from the clinical records data were then compared with aggregate RHIS clinic, district- and national reports.

11.5.2 Health system performance indicators (paper II)

Health system performance indicators were derived from guideline-based quality standards of the recommended clinical ANC interventions in the public health system in the West Bank.[124]

We included the ANC interventions that were applicable to all pregnant women and appropriate for the level of primary healthcare. Five visits were recommended as part of ANC, with specific content to be provided during each visit. According to the

national guidelines, all pregnant women attending care in public primary healthcare clinics were to be provided with eight ANC interventions (table 4). Four of these interventions consisted of repeat screenings at specified timing during the pregnancy (table 4). Screening for gestational diabetes mellitus consisted of a two-step screening process – a urine sugar test and blood sugar test. Screening tests of the remaining interventions were recommended during the first ANC visit.

The following ANC interventions were part of the recommendations in the West Bank, but not offered in primary healthcare: management of prelabour rupture of membranes and preterm labour, induction of labour for management of prelabour rupture of membranes at term, antibiotics for management of preterm rupture of membranes, management of eclampsia, and management of vaginal bleeding.

Condition-specific clinical managements were also specified in the guidelines for the following conditions detected during screening: anemia, hypertension, likely diabetes, abnormal fetal growth, urinary tract infections, and Rh negative blood group. Managements primarily consisted of referrals to high-risk (referral) clinics or to secondary and tertiary care facilities.

Three sets of metrics were assessed for the ANC interventions (table 4):

1. Coverage of at least one screening, applicable to all ANC interventions
2. Coverage of appropriate number of screenings, applicable to ANC interventions that consist of repeat screening
3. Effective coverage of ANC interventions incorporating the appropriate number and timing of screenings, applicable to ANC interventions with a specified timing of screening

Table 4: List of ANC interventions, recommended screening guidelines, definitions of coverage of at least one screening, coverage of appropriate number of screening and effective coverage of ANC interventions

ANC Interventions	Recommended screening guideline	Coverage of at least 1 screening	Coverage of the appropriate number of screening	Effective coverage of appropriate number and timing of screenings)
Screening for hypertension	BP measurement at all recommended ANC visits	Proportion with at least one blood pressure measurement	Proportion with five blood pressure measurements	Proportion with blood pressure measurements at all recommended ANC visits
Fundal height measurement to detect fetal growth abnormalities	Symphysis fundus height measurement at all ANC visits ≥ 16 weeks	Proportion with at least one SFH measurement	Proportion with five SFH measurements	Proportion with SFH measured at all recommended ANC visits
Screening for anemia	Hemoglobin test at first ANC visit, at 24-28 and 36 weeks	Proportion with at least one hemoglobin test	Proportion with three hemoglobin tests	Proportion with hemoglobin tests at first visit, 24-28 and 36 weeks
Antenatal ultrasound	One ultrasound in each trimester of pregnancy	Proportion with at least one ultrasound examination	Proportion with three ultrasound examinations	Proportion with ultrasound examinations at first visit, 24- 28 and 36 weeks
Screening for gestational diabetes	Urine sugar test at first visit, blood sugar test at 24-28 weeks	Proportion with either urine sugar or blood sugar test	Proportion with both urine sugar and blood sugar test	Proportion with urine sugar test at first visit, blood sugar test at 24-28 weeks
Screening and treatment of urinary tract infection	Urine test for asymptomatic bacteriuria during first visit	Proportion with urine microscopy test		Proportion with urine microscopy test at first visit
Blood grouping, Rh typing	Blood grouping and Rh typing in the first ANC visit	Proportion with Rh-typing		Proportion with Rh-typing at first visit
Tetanus immunization	Check history of tetanus immunization during first ANC visit	Proportion whose tetanus immunization is checked by asking for history of immunization or reviewing immunization record at booking		

ANC: Antenatal care

SFH: Symphysis fundus height

11.5.3 Lives Saved Tool indicators (paper III)

Context-specific coverage and health status indicators from ANC for input in LiST were first identified.[125] These included:

- % of women with diabetes with appropriate management
- % of women with hypertensive disorders in pregnancy with appropriate management
- % of women with appropriate tetanus toxoid vaccination
- % of women with pre-eclampsia with appropriate management
- % of pregnant women taking iron or folic acid supplements
- % of pregnant women with anemia
- % of women with severe anemia
- Low body mass index

Values of these indicators were derived from each of the four available data sources: 1) RHIS reports (2016); 2) MICS (2014); 3) paper-based clinical records (2015); and 4) eRegistry electronic clinical records (2017).

Diabetes case management and hypertension case management were calculated using data from the paper-based clinical records and the eRegistry electronic clinical records, based on management algorithms as per the recommended guidelines.
In order to calculate the case management indicators, we first estimated the number of cases in the sample given by:

$$\frac{number\ of\ abnormal\ results\ on\ screening}{\%\ screened\ \times \%\ timely\ ANC\ visit}$$

For diabetes (two-step screening) and hypertension (repeat screening during every ANC visit), each of the screening stages were accounted for and the formula subsequently included the number of abnormal results at each screening as well as the coverage of each of the screening stages.

11.6 Analysis

Statistical analyses were preformed using Stata version 15 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). Descriptive statistics were generated as weighted proportions with 95% confidence intervals (CI), using the STATA command *svyset*[126] (*papers I and II*).

Using logistic regression analysis, we studied the associations of potential explanatory variables and effective coverage of ANC interventions (*paper II*). All infrastructure-related and maternal sociodemographic variables were entered into the model as explanatory variables, and adjusted odds ratios with 95% CI were generated. Laboratory and ultrasound availability in the clinics were the two infrastructure-related variables that were included. Maternal sociodemographic variables were analyzed using the pre-defined categories available in the anonymized dataset as follows: women's age at pregnancy registration (<21 years, 21-34 years, >34 years); age at marriage (<20 years and ≥20 years); education (<10 years, 10-13 years, >13 years); and parity (nulliparous, multiparous<4, multiparous ≥4).

Analysis in the Lives Saved Tool was done using LiST version 5.71 (Avenir Health) (*paper III*). As per the LiST modeling approach, the estimate of effectiveness of the specific intervention multiplied by the change in coverage gives the number of maternal and newborn deaths, and stillbirths averted. If a single intervention is input, the underlying formula is given by:[99]
Lives saved= **(cause-specific deaths) × (change in coverage) × (intervention effectiveness × affected fraction),** where 'affected fraction' is the proportion of deaths amenable to benefit from this particular intervention.

The primary result of our LiST analysis was the difference in the number of deaths and anemia cases averted between the following two scenarios: 1) a steady state scenario where coverage of ANC interventions remain unchanged from 2017 to 2025; and 2) a scenario where coverage of ANC interventions increased to 90% from baseline in public clinics only (with no change in non-public sector health facilities) in 2018, and then remained at a steady state through 2025.

11.7 Summary of methods used

The data sources used, study design and indicators presented in the three papers that constitute the dissertation are presented in table 5.

Table 5: Overview of methods used in the papers - objectives, data sources, study design and indicators

	Paper I	Paper II	Paper III
Objective	To compare indicators routinely generated by the health information system computed from individual-level data and aggregate reports	To assess coverage of at least one screening, coverage of appropriate number of screening and effective coverage of antenatal care interventions and to explore factors associated with effective coverage	To examine the implications of multiple sources of data for modeling in the Lives Saved Tool (LiST)
Data source	Paper-based clinical antenatal records (2015) (n=1369) from 17 clinics Aggregate RHIS reports (2015): clinics, district and national reports	Paper-based clinical antenatal records (2015) (n=1369) from 17 clinics Facility inventory (2014)	Paper-based clinical antenatal records (2015) (n=1369) from 17 clinics eRegistry electronic clinical antenatal records (2017) Aggregate RHIS reports (2016) Multiple Indicator Cluster Survey (2014)
Study design	Cross-sectional study	Cross-sectional study	Secondary data analysis
Indicators	• Antenatal visits • Maternal age • Maternal anemia • Gestational diabetes mellitus • Multiple pregnancy • Malpresentation • Recurrent miscarriage • Preeclampsia • History of Caesarean section • Rhesus negative blood group • Fundal height discrepancy	Screening indicators of ANC interventions, including: • Anemia screening • Diabetes screening • Hypertension screening • Tetanus toxoid immunization • Fundal height measurement • Rh-typing • Urine analysis • Antenatal ultrasound	• Diabetes case management • Hypertensive disorders in pregnancy with appropriate management • Tetanus toxoid immunization • Pre-eclampsia management • Iron-folate supplementation • Anemia, severe anemia • Low body mass index
Statistical analyses	Descriptive statistics, weighted proportions and 95% CI	Descriptive statistics, weighted proportions and 95% CI Exploratory logistic regression analysis	Modeling in the Lives Saved Tool

RHIS: Routine Health Information System
ANC: Antenatal care
CI: Confidence Interval

11.8 Ethics approvals

Ethical approvals for data collection from paper-based clinical records were obtained from the Palestinian Health Research Council and the Regional Committee for Medical and Health Research Ethics, South-East, Norway. Approval for use of secondary anonymous data from the eRegistry was obtained from the Palestinian Ministry of Health, Ramallah, in line with the legal framework for eRegistry data use. Only pre-specified variables of completely anonymous data were obtained for the analyses. Age of women, education, age at marriage and age at first pregnancy were only available as predefined categories, as per the standard operating procedures of routine registry operations in Palestine. Clinic- and district names were not available in the dataset.

12 Synopsis of results

This section contains a summary of the results that are presented in detail in the papers that constitute this dissertation.

12.1 Paper I

Comparing individual-level clinical data from antenatal records with routine health information systems indicators for antenatal care in the West Bank: a cross-sectional study[123]

Maternal age was consistent across the clinical records data (age<16 years: 0.1%, 95% CI: 0, 0.4; age>40 years: 1.2%, 95% CI: 0.6, 2.1; 2), RHIS clinic reports (age<16 years: 0.1%, 95% CI: 0, 0.4; age>40 years: 1.4%, 95% CI: 1, 2), and nationally reported statistics for the five districts (age<16 years: 0.2%, 95% CI: 0.1, 0.3; age>40 years: 1.7%, 95% CI: 1.5, 2). Mean number of ANC visits as calculated from the clinical records data (4.5, SD 2.3) was similar to the RHIS clinic reports (mean 4.5), and nationally reported statistics from the five districts (mean 4.7).

There were 280 documented hemoglobin tests at 36 weeks in the clinical records data (20% screening coverage), compared to 890 hemoglobin tests recorded in the RHIS clinic reports (61% screening coverage) and 7602 hemoglobin tests at 36 weeks in the nationally reported statistics (52% screening coverage). The indicator anemia at 36 weeks calculated from clinical records data was 32% (95% CI: 22, 44); from RHIS clinic reports was 31% (95% CI: 29, 35); and the nationally reported statistics for the five districts was 30% (95% CI: 29, 31). Maternal conditions calculated from clinical records data, RHIS clinic reports, district reports and nationally reported statistics are presented in table 6.[123]

Table 6: Selected indicators computed from clinical records data, and those reported by care providers in the RHIS district and national reports

Reportable condition	Clinical records data - all (N= 1369)		Clinical records data - condition and referred	RHIS district reports (N= 11,416)		RHIS national statistics (N= 14,544)	
	n	Weighted % (95% CI)	Weighted % (95% CI)	n	% (95% CI)	n	% (95% CI)
Gestational diabetes mellitus	12	0.8 (0.4, 1.7)	0.05 (0.01, 0.4)	79	0.7 (0.6, 0.9)	79	0.5 (0.4, 0.7)
Multi-fetal pregnancy	20	1.3 (0.8, 2.0)	0.4 (0.2, 1.0)	84	0.7 (0.6, 0.9)	97	0.7 (0.5, 0.8)
Malpresentation at term	20	1.3 (0.6, 2.8)	0.2 (0.1, 0.7)	2	0.02 (0, 0.06)	4	0.03 (0.01, 0.07)
Recurrent miscarriages	26	1.7 (0.9, 3.5)	0.7 (0.2, 2.4)	144	1.3 (1.1, 1.5)	150	1.0 (0.2, 3.0)
Preeclampsia	7	0.6 (0.2, 1.3)	0.2 (0.02, 1.2)	26	0.2 (0.1, 0.3)	31	0.2 (0.1, 0.3)
History of Cesarean sections	93	6.4 (4.1, 9.7)	2.2 (1.3, 3.6)	631	5.5 (5.1, 5.9)	777	5.3 (4.9, 5.7)
Anemia (Hb<9.5 g/dl)	88	6.0 (4.1, 8.7)	0.9 (0.4, 2.0)	87	0.8 (0.6, 0.9)	93	0.6 (0.5, 0.8)
Rh-negative blood group	95	6.8 (4.5, 10.2)	1.2 (0.6, 2.1)	180	1.6 (1.4, 1.8)	202	1.4 (1.2, 1.5)
Fundal height discrepancy	253	20 (12.4, 30.8)	0.9 (0.5, 1.6)	None		1	0.01 (0, 0.04)

RHIS: Routine health information system

The proportion of women that were referred from the primary healthcare clinics was generally low and ranged from a maximum of 71% for preeclampsia to 16% for fundal height discrepancy. A substantial proportion were referred to health facilities that did not report on ANC indicators to the RHIS, and these data were not captured in the RHIS aggregate reports.[123]

12.2 Paper II

Effective coverage of essential antenatal care interventions: a cross-sectional study of public primary healthcare clinics in the West Bank[124]

Coverage of any five ANC visits was 48% and coverage of any four ANC visits was 60%, not considering the schedule or timing of visits. Timely, scheduled attendance at all ANC visits according to the national ANC guidelines was 6% (ANC visits <16 weeks, at 16 weeks, and at 24-28, 32 and 36 weeks). Thirteen per cent attended timely scheduled visits, when attendance was calculated disregarding early first ANC visit before 16 weeks and only considering timely visits after pregnancy registration at any time. Timely attendance of all ANC visits was 17% in clinics with a laboratory and ultrasound, and 9% in clinics without (OR 2.0, 95% CI 1.4, 2.8).

Effective coverage of appropriate and timely screening of ANC interventions ranged from a low of 6% for hypertension screening to a high of 64% for Rh-typing (table 7).[124] Coverage of at least one screening ranged between 35% for screening for tetanus immunization status to 98% for hypertension screening, and coverage of appropriate number of screening of ANC interventions ranged from 31% for anemia screening to 78% for Rh typing (table 7).

Among those that attended ANC visits according to the prescribed guidelines, 77% were screened for hypertension, 73% received antenatal ultrasound, 61% were screened for gestational diabetes, 46% had their SFH measured and 42% had anemia screening.

Table 7: Coverage of ANC interventions – at least one screening, appropriate number of screening and effective coverage, and ANC visits

ANC intervention	Coverage of ANC interventions (%, 95% CI)			ANC visits *(%, 95% CI)*	
	At least one screening	Appropriate number of screening	Effective coverage	*Number of visits irrespective of timing‡*	*Appropriate number and timing of visits‡*
Screening for hypertension	98 (96, 99)	38 (31, 47)	10 (8, 13)	*48 (38, 58)*	*13 (9, 17)*
SFH measurement	66 (50, 80)	35 (24, 48)	6 (4, 9)		
Screening for anemia	93 (89, 96)	31 (23, 40)	14 (9, 21)	*73 (62, 81)*	*33 (26, 41)*
Antenatal ultrasound	74 (59, 85)	43 (32, 54)	24 (18, 31)		
Screening for gestational diabetes mellitus	93 (88, 96)	69 (60, 77)	34 (26, 43)	*85 (77, 90)*	*56 (50, 62)*
Screening for asymptomatic bacteriuria*	55 (45, 64)		42 (36, 49)	*NA*	
Screening for Rh-type*	78 (67, 89)		64 (54, 73)	*NA*	
Screening for tetanus immunization status*	35 (23, 50)			*NA*	

ANC: Antenatal care
SFH: Symphysis fundus height
*only one screening test is recommended during ANC according to the national guidelines

Clinics with a laboratory and ultrasound had a statistically significant higher odds ratio of effective screening for the following interventions: hypertension screening (OR: 2.2, 95% CI: 1.5, 3.1), anemia screening (OR: 1.5, 95% CI: 1.1, 2.1), ultrasound (OR: 2.2, 95% CI: 1.7, 2.8), Rh-typing (OR: 1.7, 95% CI: 1.3, 2.1).

Except for parity and effective coverage of screening for tetanus immunization status (higher odds of screening for multiparity ≥4, OR: 2.1, 95% CI: 1.4, 3.2), none of the other maternal sociodemographic variables had statistically significant associations with effective coverage of ANC interventions.

12.3 Paper III

Antenatal care data sources and their policy and planning implications: a Palestinian example using the Lives Saved Tool[125]

For input in LiST, data from paper-based clinical records and eRegistry electronic records could populate all the five coverage indicators and all the three health status indicators. Two coverage indicators were available in the national statistics, while three coverage indicators were indirectly calculated (using the Kanyangarara method) from the MICS data (table 8).[125] None of the health status indicators were available from either the aggregate RHIS reports or MICS.

Table 8: Values of ANC indicators for input in LiST from RHIS aggregate reports, MICS, paper-based clinical records and eRegistry electronic clinical records

Analysis	Indicators	Aggregate RHIS reports (2016)	MICS (2014)	Antenatal Records Paper (2015)	Antenatal Records eRegistry (2017)
National baseline (applied to 2017)	% of all pregnant women who have completed the appropriate tetanus toxoid vaccination schedule	NA	NA	85.4	92.1
	% of pregnant women taking the appropriate iron or folate supplementation	NA	NA	90.3	64.4
	% of women with hypertensive disorders in pregnancy who are correctly managed	NA	68.9†	15	35
	% of women with diabetes with appropriate case management	71.9	35.1†	7	10
	% of women with pre-eclampsia during pregnancy who are correctly managed	51.7	72.9†	11	14
	Anemia	27*	27*	37.3	37.7
	Severe anemia	0.272*	0.272*	0	0.1
	BMI	3.1*	3.1*	2.8	4.4
National target assuming 90% coverage in public clinics (applied to 2018-2025)	% of all pregnant women who have completed the appropriate tetanus toxoid vaccination schedule	NA	NA	92,0	95,7
	% of pregnant women taking the appropriate iron or folate supplementation	NA	NA	94.7	80.6
	% of women with hypertensive disorders in pregnancy who are correctly managed	NA	75.5†	53.6	64.5
	% of women with diabetes with appropriate case management	84.7	47.3†	49.2	50.9
	% of women with pre-eclampsia during pregnancy who are correctly managed	73.6	74.5†	51.4	50.9
	Anemia	27.2*	27.2*	37.3	37.7
	Severe anemia	0.272*	0.272*	0	0.1
	Body mass index (BMI)	3.1*	3.1*	2.8	4.4

*LiST defaults: Finucane 2011 [127], Stevens 2013 [120]; †Using the Kanyangarara method [104]
RHIS: Routine health information system
MICS: Multiple Indicator Cluster Surveys

Using RHIS reports, increasing coverage of appropriate care to 90% in the LiST analysis, estimated that 16 maternal deaths and 239 stillbirths and would be averted. With MICS data, fewer maternal deaths (n=5) and stillbirths (n=45) were estimated to be averted. When using RHIS national statistics or MICS, no averted newborn deaths or anemia cases were identified.

The number of maternal deaths averted on increasing coverage was similar when using data from paper-based clinical records (n=35) and eRegistry electronic records (n=39). Further, 285 stillbirths and 49 newborn deaths were averted using paper-based clinical records data, while 270 stillbirths and 39 newborn deaths were averted using eRegistry electronic clinical records. While 16,444 cases of maternal anemia would be averted with paper-based clinical records, 42,064 cases were averted using eRegistry electronic clinical records. Percent reduction in the maternal mortality ratio ranged from 1% with MICS data, to 6% using ANC records data.
Preeclampsia management and hypertension disease management accounted for a large proportion of lives saved (table 8).

Table 9: Interventions averting mortality in the Lives Saved Tool using different sources of input data

Mortality/ morbidity	Interventions averting mortality and morbidity			
	RHIS aggregate data	MICS	Paper records	eRegistry
Maternal	Pre-eclampsia management (100%)	Hypertensive disease management (75%); Pre-eclampsia management (25%)	Hypertensive disease management (41%); Pre-eclampsia management (59%)	Hypertensive disease management (45%); Pre-eclampsia management (55%)
Newborn	-	-	Tetanus toxoid (100%)	Tetanus toxoid (100%)
Stillbirth	Pre-eclampsia management (84%); diabetes management (16%)	Pre-eclampsia management (52%); diabetes management (48%)	Pre-eclampsia management (83%); diabetes management (17%)	Pre-eclampsia management (82%); diabetes management (18%)
Anemia	-	-	Iron Folate (100%)	Iron Folate (100%)

RHIS: Routine health information system
MICS: Multiple Indicator Cluster Surveys

13 Discussion

The main aim of this dissertation was to assess the consequences of using individual-level clinical data to generate health- and health system performance indicators, compared to data from a household survey and the existing aggregate RHIS. There were three specific objectives. Firstly, we compared the values of routinely reported indicators calculated from clinical records data, with values in the manually reported aggregate RHIS reports. Secondly, we used clinical records data to assess effective coverage of ANC interventions and examined associations of effective coverage with clinic infrastructure and maternal sociodemographic variables. Lastly, we calculated indicator values from paper-based clinical records data, eRegistry electronic clinical records data, obtained the indicator values from aggregate RHIS reports and MICS data, as distinct inputs in the Lives Saved Tool (LiST), and assessed the implications of using the different data sources for modeling.

The joint findings supported the study hypothesis that the transition from an RHIS based on manual aggregations to an RHIS based on clinical records data will lead to significant changes in the values of routinely-reported indicators, and the interpretations of health system performance of ANC.

Pilot implementations with structural similarities to the RHIS transformation portrayed in this dissertation have been described in Rwanda[128], Malawi and Kenya, where data collected in clinical records are being used for automated generation of routine indicators and for health system performance monitoring. In many of these settings, data-related changes of RHIS strengthening efforts have been appraised in terms of completeness, timeliness and availability.[129,130] In the Kenyan setting, the assessment was primarily done to check for interoperability of electronic clinical records with an existing electronic RHIS, where only aggregated event counts were manually entered into electronic RHIS reporting forms. In this case, indicator completeness improved from 66.7% to 100% and accuracy improved from 33.3% to 100% with automated indicator calculations using clinical records data, mainly because of a reduction in transcription errors.[131]

In Malawi, point-of-care data collections were designed to overcome identified problems in the existing RHIS, such as incomplete reporting from health facilities and low motivation of healthcare staff to perform RHIS tasks. Following the introduction of a system that uses electronic clinical records data for RHIS indicators, the availability of data on clinical diagnosis and treatment information improved.[132]

The RHIS transformation, as described in section 9.6.2, was planned for implementation at scale for the entire West Bank, with the intention of replacing existing manually aggregated reports with an electronic RHIS consisting of a distinctive underlying data source for computations of indicators. In contrast to the abovementioned studies, availability and completeness of RHIS aggregate reports were not of primary concern in our study setting; all RHIS clinic- and district reports were available for the present study (*paper I*) with non-zero values of event counts.[123] Timeliness of RHIS reporting was expected to be addressed with the introduction of the eRegistry, and electronic RHIS reports were scheduled to be generated automatically every month. Beyond completeness and timeliness of RHIS reports, we included quantitative evaluations of changes in the values of routinely reported indicators compared to the RHIS aggregate reports. In addition, we have demonstrated some implications for use of data for monitoring health system performance of ANC.

13.1 Discussion of main findings

Key facets of a health information system are to develop indicators generated from data-related processes including data transmission, processing and analysis, as described by Lippeveld et al (2000).[20] The construction of indicators using clinical data can be done using two types of data: 1) sequences of datapoints with recorded results of the screening (eg. blood pressure values); or 2) dichotomous 'yes/no' response data of whether a screening was provided (eg. blood pressure measured: yes/no).[133] The former is preferable for generating indicators due to its inherent flexibilities for computations as well as for minimizing reporting bias. All routinely reported indicators (*paper I*), most of the health system performance indicators (except screening for tetanus immunization status) (*paper II*) and the indicators input

in LiST from the clinical antenatal records data (except iron-folate supplementation) (*paper III*) were constructed using the actual recorded results of screening. Similar to our study, indicator computations in the eRegistry are configured to use the actual recorded values of results of screening and management as primary data.

13.1.1 Routine Health Information System indicators

The PRISM Toolkit that accompanies the PRISM framework (described in section 9.2) recommends assessing RHIS data quality by comparing aggregate RHIS reports with the source document in health facilities.[33] Paper-based clinical records were the primary documentation source of the RHIS in our setting, documentations in clinical records preceded any other steps in the RHIS data aggregation process in the clinics.

Our findings showed that while indicator values within the existing aggregate RHIS clinic, district and national reports were largely consistent, discrepancies were uncovered between the values of some of the indicators calculated from the clinical records data and the existing aggregate RHIS reports.

In general, values of demographic indicators were consistent between the clinical records data and aggregate RHIS reports. Similar tendencies have been reported in assessments in Tanzania,[38] and Ghana,[134] where data quality was better for demographic data, compared to manual reporting of clinical risk factors or conditions.

The indicator of ANC visits had similar values when computed from clinical records data as the aggregate RHIS reports. However, ANC visits from the clinical records data had a wide distribution around the mean (mean 4.5, SD 2.3), indicating that many pregnant women in our sample did not get ANC 4+. This finding is similar to the results from two comparable health system settings – Jordan and Egypt – where a study using survey data reported wide variability in the number of ANC visits.[72] Standard deviations were not available in the existing aggregate RHIS reports.

The substantial discrepancy in the values of maternal conditions between the clinical records data and the aggregate RHIS reports can be attributed to issues related to RHIS data collection, processing and transmission, outlined in the mechanism of

change (section 9.6.2.2). Specifically based on our findings, issues contributing to the discrepancies included inconsistent denominators, errors in manual computations, and production of unreliable indicators due to a complex RHIS reporting structure.[123]

Maternal anemia at 36 weeks is an indicator of public health significance.[120,135] Our findings point towards inconsistencies in manual aggregations and manual calculations for this indicator. An overall higher number of hemoglobin tests were reported by care providers compared to the clinical records data, possibly because all hemoglobin tests were being counted and not only those done at 36 weeks. Inadequate understanding of what to report may be the underlying challenge, also identified in many other studies as a critical issue affecting RHIS data quality.[44,47,50,136] In the RHIS clinic reports, three of the 17 clinics reported more hemoglobin tests than the number of pregnancies registered in the clinic, presumably because the number of hemoglobin tests were counted as opposed to the number of pregnant women with at least one hemoglobin test at 36 weeks, resulting in less reliable indicators. Counting conditions instead of clients is not restricted to only the West Bank. In Tanzania, a study reports similar counting of number of diagnoses of childhood illness as opposed to number of children with illnesses.[38] A 14-36% error rate in reporting of anemia at 36 weeks was found in the RHIS assessment in Ghana.[134]

Factors relating to a complex RHIS reporting structure outlined in the 'data transmission' processes in the mechanisms of change (described in section 9.6.2.2), appears to have contributed to the overall discrepancy. In the existing structure of the RHIS, only referred cases with reportable maternal conditions were reported from the high-risk clinics. But our results showed a clear mismatch between the recommended guidelines for referrals and clinical practice, resulting in underestimations of maternal conditions in the aggregate RHIS reports.[123] In addition, referral practices varied among our sample of clinics. Another study in the West Bank from 2017 reported similar findings, where mean referral rate ranged from 7.3% (SD 8.3) to 12% (SD 11.7) in a sample of 39 primary healthcare clinics.[137]

A precursor for appropriate referrals is the correct diagnosis and classification of maternal conditions (mechanisms of change, described in section 9.6.2.2). Errors in the case identification process have been identified as the leading cause of poor quality of RHIS data in other settings.[136,138] In our analysis of clinical records data, we generated values of indicators of maternal conditions using constituent datapoints. It is possible that misdiagnosis or incorrect classification of conditions by care providers contributed to the discrepancy between the clinical records data and aggregate RHIS reports.

The PRISM framework, a comprehensive framework of information systems development and evaluation (described in section 9.2), does not endeavor to explicitly identify if available RHIS indicators satisfy information needs.[34] The definitions of some of the routinely reported indicators may need to be revisited, in order to improve their usability and comparability to other settings. Definitions of RHIS indicators also have implications for understanding the magnitude of the problem. Applying the WHO's diagnostic cut-offs for calculations using the clinical records data generated an indicator value of 6% (95% CI: 4-10) for gestational diabetes, compared to a value of 0.8% (95% CI: 0.4–1.7) using the existing Palestinian definition used by their RHIS.

Certain other indicators may not be valuable in fulfilling information needs, simply because clinical practices may no longer align with the reporting requirements of the RHIS. For example, fundal height discrepancy was a reportable maternal condition and recommended management is by referral. This indicator had the largest magnitude of discrepancy between clinical records data (20%, 95% CI: 12.4, 30.8), compared to the aggregate RHIS reports (0.01%, 95% CI: 0, 0.04). Our data also showed that only 6% of those with a fundal height discrepancy were referred to the high-risk clinic,[123] and as a result, no fetal growth monitoring indicators were captured in the RHIS reporting. Antenatal ultrasound is widely available and used in this region of the world; 74% of the women in our sample received at least one documented ultrasound.[124] Further, we found that in clinics with ultrasound equipment, only 29% of the women had a fundal height measure.[124] Given this, better

understanding of fetal growth monitoring in public clinics would require a comprehensive screening strategy as well as including ultrasound results of fetal growth monitoring as part of RHIS reporting.

13.1.2 Health system performance indicators

In settings with an electronic RHIS, the PRISM Toolkit suggests assessing whether the RHIS can provide denominators for calculating coverage of ANC first visit.[33] More detailed evaluations were warranted in our setting, given the nature of the RHIS transformation.

Early first ANC visit before 12 weeks (47%, 95% CI: 38, 55) was lower in our study compared to other reported figures from the Middle East and North Africa region using population-based survey data, where proportions attending an early first ANC visit ranged between 70-80%.[139] According to MICS 2014, 93% of the respondents had a first ANC visit in the first trimester in the West Bank.[109]

While almost half of all the women in our sample had at least five ANC visits, coverage of appropriately timed ANC visits was lower at 13%. Underlying contributing factors to the low coverage of appropriately timed ANC visits may include care providers' insufficient knowledge of ANC guidelines, inadequate training and supervision, lack of ANC utilization by pregnant women or combinations of these factors. Frequent use of antenatal ultrasound, purportedly a common practice in the West Bank, could inflate the coverage of any five ANC visits, compared to ANC attendance according to the recommended schedule during which other important ANC interventions are to be provided. A study in Syria assessing antenatal ultrasound use found that women's preference for repeated ultrasound scans may result in frequent visits to the clinics during pregnancy, where ultrasound was performed while other care content may not be provided.[140]

Coverage of at least one screening test, as defined in our study, is the conceptual equivalent of what other studies have reported as ANC "content"[72,141,142] or "quality"[6,71] or "adequacy".[81,139] In these studies, data sources used to quantify ANC content include survey data,[72,81] self-reported journals of clients,[141] direct

observations of ANC at health facilities,[7] clinical records data[142] or a combination of population-based survey and health facility data.[143] Coverage of at least one screening can, therefore, be interpreted in light of such studies, with due awareness of the fundamental differences in the underlying data sources.

Any blood pressure measurement and hemoglobin testing are two ANC interventions that have relatively high coverage in many other LMIC.[71,72] Similarly, in our analysis, the coverage of at least one screening of blood pressure and hemoglobin was over 90%.[124]

Screening for tetanus immunization status had the lowest coverage (35%) of all the ANC interventions. In Jordan, the coverage of tetanus immunization during ANC was found to be 31.5%.[72] In LMIC with lower institutional delivery rates than in our study setting, screening and providing tetanus immunization during ANC are critical indicators to monitor.[144] Hospital delivery rates are high in both Jordan and the West Bank (>98% institutional delivery),[107] and no cases of neonatal tetanus have been reported in the West Bank in the past 4 years.[107] The underlying reasons for low coverage of screening for tetanus immunization status during ANC need further exploration.

We assessed two additional metrics: 1) coverage of appropriate number of screenings (not factoring in timing of screening); and 2) effective coverage of ANC interventions. According to our definitions, percentage screening multiplied by timely attendance rates gives effective coverage of ANC interventions. Hence, both attendance and ANC content are, theoretically, equally important drivers of effective coverage. Our findings indicate that the gap towards "100% timely attendance" is larger than the gap towards "100% coverage of interventions" in the West Bank. The lowest intervention coverage was for tetanus immunization at 35%, while only 13% of women attended all recommended visits in a timely fashion. We have, therefore, presented this as one metric "effective coverage of ANC interventions", to indicate quality-corrected coverage to quantify the provision of clinical ANC interventions. Consequently, for ANC interventions consisting of one-time screening, the difference

between coverage of at least one screening and effective coverage of ANC interventions was less pronounced.[124]

Poor quality of ANC, measured in terms of the receipt of a set of clinical ANC services, has been highlighted in many studies.[71,72,81] The "quality-coverage gap" is one of the main contributors to the low effective coverage of ANC in LMIC.[6,71] Effective coverage of ANC was about 45% in Kenya,[83] 50-80% in different states in Mexico,[145] and about 20%-50% in eight LMIC.[7] The authors of the Lancet commentary on maternal and child health in the occupied Palestinian territory allude to frequent ANC visits with poor content of care, and care that does not always consist of evidence-based interventions.[116] Our finding of relatively low effective coverage of ANC interventions has commonalities with a multi-country study using survey data, where ANC content was quantified as the coverage of six routine ANC interventions. The study found that the coverage of ANC interventions among women that had ANC was lowest in Jordan (9.9%) among the 10 included LMIC.[72] In Oman, coverage of ANC content, assessed in terms of at least one blood pressure measurement, blood and urine samples taken, an ultrasound and counseling for danger signs using population-based survey data, was 71.7% although 96.8% had four or more ANC visits.[139] Despite fundamental differences in the data sources and metrics used, a general trend may be noted between these studies and our finding of low effective coverage of ANC interventions.

Health facility surveys such as SPA and SARA collect data on clinic infrastructure availability that serve as input measures of quality of care. However, recent evidence showed a modest correlation between the availability of infrastructure and clinical ANC content in the sub-Saharan African setting.[146] In our study, some of the statistical associations between effective coverage of ANC interventions and clinic infrastructure availability were intuitive to explain. For example, clinics with laboratory and ultrasound availability had a higher effective coverage of laboratory-dependent screening such as for anemia and Rh-type. The lower effective coverage of SFH in clinics with infrastructure availability is perhaps due to the use of ultrasound for fetal growth monitoring in these clinics. Timely scheduled ANC attendance was

higher in clinics with infrastructure (17%) compared to clinics without (9%), and this can explain the higher effective coverage of hypertension screening in clinics with infrastructure availability.

In our analysis of associations of maternal sociodemographic factors and effective coverage, we were reliant on the equity stratifiers collected in the paper-based clinical records, namely, mother's age, age at marriage, education and parity, each with predefined categories of data. In many LMIC, routine data for equity analysis are mainly available from censuses and vital registrations, and some equity-data are usually collected in household surveys.[61] Health facility and administrative data are less common sources of data on equity stratifiers. Further, studies of inequities in maternal and child health services or outcomes have used population-based data and are probably better poised to unravel sociodemographic disparities,[80,147] which may not have been captured in our study using health facility data of those who seek care. Besides, commonly used equity stratifiers such as household expenditure, individual income or household wealth index were not available for analysis in this study.

Ideally, the metric of equity and the metric of health required for equity analysis are available from one data source.[61] Household income and number of members in the household (to calculate average monthly household income) were two data points added to data collections in the eRegistry, in an attempt to capture more robust equity stratifiers alongside individual-level health data (data not included in the present study).[113]

13.1.3 Lives Saved Tool analysis

LiST is a linear mathematical modeling tool.[100] LiST models are characterized as deterministic, that is, the model output, consisting of population-level risk factors and cause-specific mortality, is determined by the specified parameters of changes in intervention coverage.[100] Several research studies using LiST have acknowledged that the validity of LiST outputs depend on the quality and availability of input data, acknowledging this as a general limitation for modeling.[103,148] However, few studies have assessed the implications of using different sources of data for modeling in

LiST. Default values of coverage and health status indicators are provided in the LiST software; the values can be modified with locally available data and estimates.

As far as we are aware, this is the first study to assess implications of using different data sources for modeling of ANC in LiST. Through our findings, we have illustrated the implications of using data sources that commonly constitute a health information system in LMIC for computing intervention coverage, including population-based MICS, RHIS aggregate reports and clinical records data.[125] Until this study, LiST had not been used in the Palestinian health system setting.

Munos et al found that household surveys were generally unsuitable sources of data for measuring coverage of interventions that are complex and require clinical data for calculations.[93] Our findings reiterated this; none of the LiST input indicators were directly populated by the MICS data. Given the general lack of availability of measured indicators for input, Kanyangarara and Chou (2017) developed a method to obtain indirect estimates of intervention coverage for LiST with focus on sub-Saharan Africa.[104] In this method, predicted values of intervention coverage are derived through a linking approach of commonly available data on ANC from population-based surveys – ANC 4+, early first ANC visit before four months, and blood or urine sample taken during ANC – with data from facility surveys like SPA or SARA. Coverage of diabetes and hypertensive disease case management are two LiST indicators that do not typically have readily available measured data.[148] These were available from the paper-based clinical records data and the eRegistry electronic records, while the method proposed by Kanyangarara and Chou was used to generate estimates of "likelihood of care" using proxy indicators from MICS and RHIS aggregate reports. As an illustration of how measured coverage and estimates of "likelihood of care" compare, we applied the prediction formula to paper-based clinical records data; the resulting indirect estimate for hypertension case management was 62%, which is a considerable overestimate of the measured case management indicator of 15% based on measured coverage of appropriate screening and management.

Of the four data sources used in the LiST analysis, measured data for direct calculations of indicators were available from paper-based clinical records and eRegistry electronic clinical records. Consequently with these two data sources, comparatively fewer assumptions were required while generating input indicators.

The absolute mortality reductions were small in the study context (1-6% in maternal mortality, and 0-3% for neonatal mortality, stillbirth cases and anemia cases). In settings with higher mortality and morbidity levels than the West Bank, these results are likely to be magnified. Similar numbers of maternal, newborn and stillbirth lives saved were obtained with input data from paper-based clinical records and eRegistry electronic records, except for the number of anemia cases averted. The two-fold higher number of anemia cases averted with the eRegistry electronic record compared to paper-based clinical records (42,064 vs. 16,444) could be due to the underlying differences in the data capture process between the two systems. In the paper-based clinical records, datapoint of iron-folate supplementation was collected as a single checkbox to indicate whether or not supplements were provided. This might have overestimated performance with respect to this indicator in the paper-based clinical records, compared to the eRegistry. In the eRegistry, clinical management data are collected more systematically with validation rules for data entry. This highlights the need to consider exactly how questions are asked in an electronic RHIS in order to obtain the most useful data for action.

The interventions averting deaths were distinct for each data source used, and even when there was some degree of overlap, the composition of interventions averting deaths varied. Using MICS data as the input, efforts to reduce maternal mortality should be focused on strengthening hypertension disease management (75% of mortality and morbidity averted by hypertension disease management), whereas using RHIS aggregate data indicated that all efforts should target preeclampsia management (100% of mortality and morbidity averted by preeclampsia management). Similarly, for stillbirth reduction, improving coverage of diabetes case management would be down-prioritized compared to pre-eclampsia management if clinical records data

were used, while with MICS data for LiST modeling the coverage of both of these interventions would then get equal priority.

This LiST analysis per se has some limitations. The different data sources for coverage data were from slightly different time periods (2014-2017), while maternal mortality estimates were derived from 2015 WHO reports.[108] We assumed that referral of pregnant women is an indication of receiving appropriate care, which may not be the case. For instance, appropriate management of preeclampsia, according to LiST definitions is with magnesium sulfate. Yet, the lack of use of magnesium sulfate has been pointed out in the West Bank.[116,118]

In our analysis, we modeled mortality reductions through increased coverage of just ANC interventions, which may still only explain a small proportion of lives saved. Obstetric services and interventions during labor and delivery, and postnatal care have been demonstrated to be important, and perhaps more effective in averting maternal and neonatal deaths in many other LMIC.[149]

LiST has inherent technical restrictions that are also applicable to our analysis. There is some degree of fundamental uncertainty in the effectiveness estimates of ANC interventions. The mortality rates used in LiST are themselves derived from modeled estimates.[108] Validation studies comparing LiST models with measured mortality reductions can provide an understanding of the validity of the modeled results. For instance, validations studies of child mortality reductions found that modeled projections of mortality estimates were reasonable matches to the measured estimates in Ghana[150] and South Asia,[151] while LiST models were found to underestimate actual mortality reductions Mali.[150] Maternal mortality projections of LiST have not been validated, and this is an important limitation. No validation studies have been conducted for LiST projected mortality reductions for a health system setting in the Middle East and North Africa region, and subsequently, many of the assumptions in modeling may be inappropriate for the West Bank. Finally, the assumed target coverage of ANC interventions of 90% in the public clinics may not be feasible to achieve, considering that the public health system in the West Bank already suffers from several financial constraints.[117]

13.2 Health system implications

Strengthening of health information systems in the Eastern Mediterranean region has been identified as a priority by the WHO.[152] The present study was performed in a real-world RHIS transformation. We have used context-specific indicators that were either already routinely available in the Palestinian RHIS (*paper I*), or were part of MICS (*paper III*), or based on the recommended clinical guidelines in the public health system (*papers II, III*). These increase the relevance of our findings to health systems managers in the West Bank.

Our findings have immediate significance for the health system as they were presented to the Palestinian Ministry of Health, in order for them to understand that transitioning from an RHIS based on manual aggregations to an RHIS based on individual-level data will lead to significant changes in the values of routinely-reported indicators. Lomas (1997) emphasized the importance of better cooperation of researchers and policy-makers, in order to achieve maximum gain in sound policy-making based on evidence.[153] In keeping with this philosophy, all results mentioned in this dissertation were presented to the Palestinian Ministry of Health, in an attempt to foster uptake of study findings and interpretations by those that are able to take action based on health information.[34] Efforts to increase RHIS data quality are critical towards strengthened data-driven decision-making and quality improvement efforts of health systems.[129,154]

In terms of use of indicators for routine health systems monitoring, it should be highlighted that all of the health system performance indicators of ANC interventions presented in this dissertation may not carry equal relevance. While the identification and finalization of national ANC guidelines were derived through expert opinion and consensus, the indicators themselves have not yet been subjected to any evaluations to assess their use in the health system. The RAND/UCLA Appropriateness method is one methodology that could be used to arrive at an optimal list of indicators for routine health systems monitoring in the West Bank.[155] Purposeful selection of indicators for routine monitoring could also be done based on burden of disease of maternal and child health conditions in Palestine, and tailored to reflect specific

stakeholder perspectives or according to the level of care provision.[155] Guidelines for the number and timing of ANC visits, and the clinical ANC interventions are periodically revised according to emerging evidence,[156-159] and the corresponding indicators should subsequently be updated.

In order to make appropriate interpretations of health systems implications, it is important to understand the calculations underlying the metrics. In calculating the effective coverage of ANC interventions, we adopted an "all or nothing" approach,[133] that is, we calculated the proportion of pregnant women receiving all screening tests, if they are registered for ANC in public clinics. Other analytic approaches such as "opportunity scores" and "average of averages" could be tested.[133] In the "opportunity scores" approach, the denominator only takes into account the instances when women had ANC visits after registration of pregnancy and the numerator counts all instances in which the intended ANC interventions are provided.[133] With an "average of averages" approach, each individual pregnancy is assigned a score based on screening and appropriate management during ANC, and an average of the individual scores is subsequently generated for the health facility.[133] In addition, if such performance indicators are to be implemented in practice to monitor health system performance, several other aspects should be considered by health systems managers and decision-makers, such as acceptability, feasibility, reliability, sensitivity and predictive validity of the metrics.[155]

Crucial factors that determine RHIS performance according to the PRISM framework include organizational factors of governance, resource-availability, training and supervision, and behavioral factors such as demand for data and motivation of healthcare staff. Demand for data and health workers' motivation for behavior change will play a vital role in improving RHIS and health system performance.[32] In the long run, organizational and behavioral factors are crucial for the sustainability of an electronic RHIS, as has been demonstrated in other settings.[160,161]

Certain issues with RHIS documentations and reporting will not be directly addressed just with the introduction of the eRegistry, but warrants training of care providers. For instance, 1463 pregnancies were registered in the 17 clinics according to the

aggregate RHIS reports submitted by the care provider, while only 1369 of these had a paper-based clinical record, leaving 94 pregnancies presumably with no documentation trail.[123]

The PRISM framework has a restrictive definition of health system performance and includes only two aspects of a health systems that can directly be subjected to monitoring through RHIS, namely healthcare service delivery and resource management.[32] This dissertation has a similar underlying premise. Any RHIS, be it an aggregate paper-based system or an individual-level eRegistry, is primarily designed to capture health facility data, and may not be suited for routine capture of data to assess other aspects of quality of health systems. While effective coverage of ANC interventions capture effectiveness of care to monitor service delivery, patient-centeredness and user-experience, efficiency and responsiveness of health systems are some of the other critical aspects of health system performance that still need to be monitored for ensuring health systems quality.[133]

13.2.1 RHIS data in a fragmented health system

Our study design fulfils the objective of this dissertation of assessing the changes to the values of indicators due to the RHIS transformation in public clinics, and the findings can provide insight into ANC provided in public clinics.

However, in order to make stronger interpretations of the overall care *received* by pregnant women from the entire health system based on the results of the present study or using data from the transformed RHIS, better understanding is required as to where women seek ANC, and whether or not they shift between public, private and other healthcare providers. As per the Palestinian Ministry of Health, 40-50% of all delivering women attended ANC in public clinics in the West Bank; similar to health systems in the Middle East and North Africa region in general.[162] According to MICS 2014, only about 20% reported attending ANC in public clinics. We did not have data on the actual ANC utilization pattern in our sample of pregnancies, to understand if women registered for ANC in public clinics also seek additional services in non-public sector health facilities.

From the wider health systems perspective, an RHIS that only includes data from one part of a scattered health system may not reach its full potential in serving the needs of policy makers, whether it is a traditional paper-based system or one transformed into an electronic health registry. Shengelia et al (2005) in their foundational article on effective coverage, highlight the role played by the national health authorities as stewards in ensuring not just access to healthcare services in public clinics, but also that the clients get potential health gain.[73] Including private sector statistics in the RHIS could provide better understanding the health system, the importance of which has been highlighted for LMIC in general, where health systems are fragmented.[163]

13.3 Discussion of methods

13.3.1 Study design

A cross-sectional study design was used to collect paper-based clinical records data. This study design was suitable for the present study, where the goal was primarily to provide descriptions using the data. Cross-sectional studies have many advantages, including the feasibility and relatively inexpensive nature of data collection. Such a design allows for several outcomes to be assessed simultaneously,[164] as presented in this dissertation, where one data collection from paper-based clinical records was used to assess three sets of outcome indicators. Cross-sectional studies are unsuitable for drawing causal inference.[164] They can, however, provide indications of associations between the outcome and the explanatory variables of interest. In *paper II*, logistic regression analysis was done with the primary purpose of gaining an understanding of the associations between effective coverage of ANC interventions and infrastructure-related and maternal sociodemographic variables.[124]

In order to address the first two objectives of this dissertation, paper-based clinical records data were used for two reasons. First, we wanted to compare values of indicators calculated from clinical records data with manually aggregated RHIS reports submitted during the same period, and for the year immediately prior to the RHIS transformation.[123] Second, we wanted to generate values of indicators and evaluate the data-related changes that were attributable to the nature and properties of individual-level data collected at the point-of-care, without having to account for

possible influences from using an electronic health information system. At the same time, the structure and content of the electronic form for data entry from the paper-based clinical records were set up to be identical to the eRegistry electronic clinical records so as to ensure that our findings are a reflection of the expected data-related changes of the RHIS transformation.

The final dataset of paper-based clinical records was obtained by double data entry along with quality checks of data, a technique widely used in epidemiologic research to improve data quality.[165] We used sample weights in the analyses of paper-based clinical records data, which is recommended for survey data to produce robust standard errors.[122]

In the West Bank, a clinical record is supposed to be opened for every woman registered for ANC in public clinics. The paper-based clinical records were retained at the clinics, and supposed to be stored for up to 5 years after the expected completion of the pregnancy. Retrieving paper-based clinical records may not be feasible in other LMIC.

The number of women that were registered for ANC in each clinic was known from a facility inventory assessment done towards the end of the year preceding the data collection for the present study, and appeared to be fairly constant over time, enabling us to establish appropriate denominators to transform event counts from aggregate RHIS reports to proportions, and subsequently make comparisons. Often, populations are mobile resulting in difficulties in establishing denominators, negatively impacting the validity of indicators generated using RHIS data.[68]

In terms of documentation and reporting in the paper-based system, RHIS processes in the clinics throughout the West Bank were generally homogenous, and all clinics in the various administrative districts were obliged to report on the same set of indicators as that included in our study as part of RHIS reporting. As of 2018, there were no vertically organized donor-funded programs of maternal and child health in the West Bank that would require separate reporting. In many other LMIC, fragmented RHIS reporting systems[51] and over- or under-reporting of indicators have been described, conditional on donor-funded programs.[38] A study of RHIS processes

and changes in values of indicators in a sample of clinics in these other settings should also account for such factors, before the results can be generalized to the larger geographical area from which the sample is derived.

Preceding the data collection and analyses of the present study, extensive processes of identifying and refining guidelines of ANC in primary healthcare had already been undertaken,[113] which then made it possible to define effective coverage of ANC interventions and case management indicators for LiST. All public clinics, irrespective of size and infrastructure availability, are prescribed the same set of national ANC guidelines and can, in theory, be subjected to health systems monitoring with the same ANC indicators, similar to those presented in this dissertation.

A potential limitation of the data collection from paper-based clinical records is the smaller sample of clinics (n=17), relative to the total number of clinics in the study area (n=165) and the West Bank. The clinics in our sample did not vary in terms of profiles of healthcare staff; all clinics in our sample had a nurse or midwife providing ANC, with doctors visiting once a week. A larger number of clinics may have allowed for the examination of effects based on geographic location of clinics, profiles of health care staff or other infrastructure-related differences. In contrast to our sampling strategy, the estimated sample size of pregnancies could have been achieved by selecting a larger number of clinics, and then performing a simple random sampling of equal numbers of paper-based clinical records from each clinic. This sampling approach is commonly used in household surveys, where the objective is to select individuals from widespread geographical areas so as to generate population-representative estimates,[166] as opposed to the mainly clinic-level assessments presented in this dissertation.

13.3.2 Assumptions in using clinical records data

In our study, we made certain assumptions that may be considered appropriate for any study that uses data from clinical records.

First, we assumed that documentation was proof of having provided the healthcare service, and lack of documentation was regarded as an absence of having provided care. This may not necessarily be problematic for outcome indicators presented here; data points used for analyses in papers I, II and III are of importance for optimal clinical care for the care provider, and would therefore be important to document irrespective of the relevance of data for RHIS reporting or health systems monitoring. Gestational ages were estimated as per standard clinical practice in primary healthcare in the West Bank and were available in both paper and electronic clinical records.

Second, we assumed that all clinical documentations were primarily done on the clinical records pertaining to individual clients. However, this may not be the case, and alternative documentations may be carried out in the clinics. One additional documentation source is the Maternal and Child Health Handbook, introduced in 2008 in Palestine as personal records held by pregnant women.[114] The Handbook contains the same information as the clinical records, including clinical examinations and results of lab tests. A study done in Kenya comparing different sources of documentation in clinics showed that data completeness was highest in the MCH Handbooks out of all documentation sources.[55] We did not compare completeness of clinical records versus MCH handbooks, since only the data from the clinical records are captured in the eRegistry and made available in the RHIS.

As such, these assumptions are unlikely to have adversely impacted the interpretation of our findings, given that the definitions and calculations of values of indicators were aligned with the expected data collection processes of the eRegistry.

13.3.3 Generalizability

Generalizability is the extent to which the results of the study can be transferred to other settings or populations.[167] In principle, such types of calculations using individual client-level data can be set up in any RHIS and subsequently, the implications ensuing from these fundamentally different data capture systems presented in this dissertation can be generalizable to other settings.

Maternal age, anemia at 36 weeks and ANC visits are important indicators that are typically reported as part of RHIS reports in many LMIC. The sequence of first documenting in clinical records and then manually copying select data to clinic registers, and manually aggregating to monthly reports reflects a fairly standard set of RHIS processes in most LMIC, and published studies have reported an identical RHIS process in health facilities in South Africa,[37] Benin,[44] Malawi,[47] Ghana,[134] the Philippines,[136] Indonesia,[138] and Mozambique.[168] Many of these studies have also identified steps where the greatest proportion of errors occur in a given setting, whether during manual counting of events, copying of data from clinical records to clinic registers, or during the preparation of monthly reports. An RHIS data quality assessment in the context of prevention of mother-to-child HIV transmission showed that there were significant errors during the data collation process from the clinic registers to monthly reports.[36] Similar results were also observed in the context of immunization reporting.[40] One study from Tanzania showed that with every additional step in the handling of data, the chance of error increases by two times.[169] Using clinical records directly for electronic automated computations of indicators in these settings will probably provide similar results as our study, simply by minimizing transcription errors involved in manual handling of data.

WHO's 2016 guidelines for a positive pregnancy experience are empirical recommendations meant to be adopted by LMIC in general.[87] Three of the ANC interventions included in our assessment were similar to the WHO's essential interventions (screening for hypertension, anemia, and tetanus immunization status),[86] while another three are recommended as part of the WHO's guidelines for a positive pregnancy experience (SFH measurement, screening for gestational diabetes mellitus, and asymptomatic bacteriuria).[87] Health system performance indicators based on context-specific clinical interventions can be used for health systems monitoring in other LMIC through a similar approach of using individual-level data collected at health facilities.

The implications of various data sources on model-based program planning and evaluation are relevant in the many settings where LiST is used. Different resultant

numbers of deaths averted, morbidity reduction and compositions of interventions averting deaths raises critical questions for the importance of input data in LiST.

Nevertheless, large-scale implementations of electronic health information systems with point-of-care routine individual-level data collections are complex, resource-intensive, and have high initial start-up costs. Such implementations are often perceived as infeasible in low resource settings. This can limit the applicability of this model of RHIS in other LMIC, despite our findings of better validity of routinely-available RHIS indicators, and the availability of more granular data for health system performance indicators and program planning using a modeling tool.

14 Summary and conclusions

A health information system that provides routine, good quality data is one of the pillars of the health system. Digital health interventions offer unprecedented opportunity for improving the availability of health systems data. Simultaneously, utilization of health services has increased enormously in most LMIC, and health facility data collected during clinical care can be a viable as well as important source by itself. In addition, facility-based clinical records could also complement population-based surveys for more comprehensive monitoring.

Bearing these in mind, the following general conclusions can be drawn from our findings:

- An RHIS that uses individual-level clinical data to produce RHIS reports can eliminate transcription errors in data aggregation, and subsequently improve the reliability of routinely reported indicators.
- The choice of metric used for health systems monitoring of ANC, can have an impact on ascertaining the magnitude of the problem as well as identifying potential solutions. Effective coverage of ANC interventions, a comprehensive measure of effectiveness, can help understand if complete care is provided at appropriate times during the pregnancy.
- Various data sources commonly used to support evidence informed decision-making at national levels have pros and cons, and subsequently, selection of the most complete and appropriate data source for policy and planning is critical. Individual-level clinical data can provide the largest quantity of data for calculations of indicators and be a solid basis for local decision-making processes.

Specifically for the West Bank, Palestine, the following conclusions can be drawn:

- As the RHIS transitions from manually aggregated data to the eRegistry, the values of routine indicators will be different from what were available in the existing reports consisting of manual calculations. The values of the indicators produced in the eRegistry are more complete and capture the health status of

pregnant women receiving ANC in public primary healthcare clinics more accurately.

- Effective coverage of ANC interventions in public clinics in the West Bank can be increased by improving the timely and complete provision of ANC interventions. Some aspects of care provision, such as care providers' adherence to guidelines, and women's utilization of ANC services, should be explored further to understand and address the underlying factors to increase effective coverage.
- The LiST analysis demonstrated notable variability of information available for decision-making based on the data source chosen. Program managers and decision-makers should be aware of the implications of the data source used, in order to make informed decisions.

15 Future perspectives

Several avenues for future research have emerged from the present study, some of which are listed below as research questions.

General:

- How can the approach of routine point-of-care data collections of individual-level clinical data be implemented at scale in health facilities in other LMIC?
- What factors would determine the feasibility and acceptance of such a system?
- What is the cost-effectiveness of an RHIS based on such a system?

Methodology:

- What is the validity of using clinical records data for performance monitoring? How does it compare to direct observations and health facility surveys?
- How can other metrics of health system performance indicators be calculated?
- Can linking approaches of population-based survey data and clinical records data from health facilities be used for establishing population estimates of effective coverage?

RHIS data quality:

- How can we standardize assessments of quality of RHIS data and indicators generated from individual-level clinical data?

Effective coverage of ANC interventions:

- Can performance indicators of effective coverage of ANC interventions be operationalized in LMIC?
- What is the reliability, sensitivity and predictive validity of the indicators of clinical ANC interventions that measure if appropriate and complete screening was provided?

Lives Saved Tool analysis:

- How can we create a framework that characterizes and supports evidence-informed decision-making at national levels, based on the pros and cons of various data sources?

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17 Appendices

State of Palestine

Ministry of Health

دولـة فلسـطين

وزارة الصحة

سجل رعاية ومتابعة الحمل
Antenatal Record

MCH / Viliage Center		مركز رعاية / أمومة
Governorate		المحافظة
Date of First Visit		تاريخ الزيارة الأولى
File No.		رقم الملف
Personal ID No.		رقم الهوية الشخصية / جواز السفر

Address / العنوان

المدينة City	القرية Village	الحي Street	الهاتف Telephone

Mother's of Education in Year		سنوات تعليم الام

درجة القرابة بين الزوجين: ☐ درجة أولى ☐ درجة ثانية ☐ درجة ثالثة ☐ لا يوجد

Personal Identification		التعريف الشخصي	
العائلة قبل الزواج Family befor Marriage	اسم العائلة Family Name	اسم الأب Father's Name	الاسم الأول First Name

Date of Birth / تاريخ الميلاد

اليوم Day	الشهر Month	السنة Year

Age at Marriage		العمر عند الزواج
Age at first pregnancy		العمر عند الحمل الأول
Husbands name		اسم الزوج الثلاثي

Current Pregnancy — الحمل الحالي

Obstetric History	عدد مرات الحمل Gravida	عدد الولادات Para	مرات الإجهاض Abortion	أطفال أحياء Living	تاريخ آخر ولادة LD	السيرة الولادية السابقة

1) LMP C005	يوم Day / شهر Month / سنة Year	١) تاريخ آخر ولادة
2) First fetal movement	يوم Day / شهر Month / سنة Year	٢) أول حركة للجنين
3) EDD C006	يوم Day / شهر Month / سنة Year	٣) التاريخ المتوقع للولادة
4) Conception During Breast Feeding C002/14	Yes = 1 / نعم = 1 ☐ No = 2 / لا = 2 ☐	٤) حمل أثناء الإرضاع
5) Gestational age at first Visit (weeks) C008	----------	٥) عدد أسابيع الحمل عند أول فحص
6) Using medications C001, if yes, when, what?	Yes = 1 / نعم = 1 ☐ No = 2 / لا = 2 ☐	٦) استخدام الدواء. متى وما هو؟

Specify ---------- حدد

7) Medical & surgical Condition C010: — ٧) الحالة المرضية

01	Abdominal surgery	06	Mental disturbance	11	Uterine anomaly or injury
02	Cardiac disease	07	Renal disease	12	Anemia (Specify)
03	Cervical suture	08	Type I Insulin dependent DM	13	Bronchial Asthma
04	Epilepsy	09	Type II Insulin dependent DM	14	RTIs
05	Hypertension	10	Gestational DM.	15	Others
88	Others				

8) Cervical Cytology (Pap Smear) C004 — ٨) المسحة الخلوية لعنق الرحم

1. Done 2. Not Done

If Done –

1. Normal 2. Ubnormal

Specify ----------

9) Family History — ٩) أمراض عائلية

1. Diabetes 2. Hypertension 3. Renal 4. Heart 5. Congenital Anomaly
6. Inborn error of metabolism 7. Blood Disease 8. Bronchial Asthma

Risk Assessment

تقييم عوامل الخطورة

A) Risks related to Medical & Obstetrical History (On booking) C012

أ) العوامل المتعلقة بالسيرة المرضية والولادية

Age <16,> 40 year	العمر أقل من 16 سنة أو أكثر من 40 سنة	Y	N	Post APH	سوابق نزف قبل الولادة	Y	N
Consecutive Abortions (>=3)	■ 3 إجهاضات متتابعة أو أكثر	Y	N	Post PPH	سوابق نزف بعد الولادة	Y	N
Peri-natal Deaths (>=2)	وفيات حوالي الولادة (2 أو أكثر)	Y	N	* Diabetes M. (type)	* مرض السكري (النوع)	Y	N
Previous C-Section	■ سوابق عمليات قيصرية	Y	N	* Chronic Hypertension	* ارتفاع توتر شرياني مزمن	Y	N
Other uterine Surgery	■ سوابق جراحة رحمية أخرى	Y	N	* Heart/Renal Disease	* مرض كلوي/ قلبي	Y	N
Multiparty (>=6)	6 ولادات أو أكثر	Y	N	Others (Specify)	أمراض أخرى	Y	N

B) Risks Related to Current Pregnancy

ب) العوامل المتعلقة بالحمل الحالي

Date Of Visit تاريخ الزيارة	Booked visit	28 weeks	32 weeks	36 weeks	Others
Gestational Age عمر الحمل بالأسابيع					
Gestational Diabetes Mellitus (GMD) مرض سكري الحمل					
SIGNS Of Pre-Eclampsia عوارض تسمم الحمل					
Vaginal Bleeding نزيف أثناء الحمل					
Moderate Anemia (HB<9.5 g/DL) فقر دم متوسط (خضاب أقل من 9.5 جم)					
Discrepancy of Fundal Height عدم توافق ارتفاع الرحم مع فترة الرحم					
Oligo/ Polydraminous زيادة أو نقصان في السائل الامنيوسي					
Malpresentation At>=36 Weeks سوء توضع الجنين اعتباراً من 36 أسبوعاً					
Loss Of Fetal Movement >24 Weeks عدم الشعور بحركة الجنين بعد 24 أسبوعاً					
Multiple Pregnancy حمل متعدد الأجنة					
PROM تمزق الأغشية الجنينة المبكر					
RH Incompatibility تنافر العامل الرايسي					
Pregnancy with pelvic mass ورم في الرحم مع وجود حمل					
Others أخرى (Specify) (أذكر) ----------					
Name Who Perform The Assessment اسم من قام بالتقييم ----------	التوقيع	التوقيع	التوقيع	التوقيع	التوقيع

* تعني الرجوع إلى نظام التحويل (الصحة الإنجابية)

■ تعني التحويل إلى عيادة الحمل الخطر

سيرة الحمول السابقة (وتشمل الإجهاضات)

Previous pregnancies (including miscarriages)

الرقم No.	تاريخ الحمل Date of Pregnancy	عمر الحمل اسبوع Gestational Age C008	طريقة الولادة Mode of delivery C030		مكان الولادة Place of birth C039	مضاعفات الحمول السابقة والولادة والنفاس Previous pregnancies C012 (obstetric problems) & Postnatal Problems C045	المولود Newborn		
			Vaginal	Abdominal			النوع Sex B013	الوزن الولادي BWt. "gr" C055	Birth outcome C034
01									
02									
03									
04									
05									
06									
07									
08									
09									
10									
11									
12									
13									
14									

Additional Remarks on Previous Pregnancies ملاحظات إضافية على سيرة الحمول السابقة

Place of Delivery ---------- مكان الولادة

Intended Place of Birth C038	مكان الولادة حسب رغبة الأم
Recommend place of birth	مكان الولادة (حسب توصية الطبيب)
Stamp & Signature التوقيع والختم ----------	Doctor's Name اسم الطبيب ----------

Antenatal Follow – up

سجل متابعة ورعاية الحوامل

Gravida الحمول		USS		Tests تحاليل أولية	Results النتيجة	Date التاريخ	Hb الخضاب	Date التاريخ	/ /	/ /	/ /	/ /	/ /
		Date	Results	Blood group				Results النتيجة					
Parity الولادات		/ /		Rh typing			Blood sugar	Date التاريخ	/ /	/ /	/ /	/ /	/ /
اجهاضات Abortions		/ /		Indirect Comb's				Results النتيجة					
تاريخ آخر LMP حيض	/ /	/ /		Other Tests اختبارات أخرى									
التاريخ EDD المتوقع للولادة	/ /	/ /		Date	Test	Results	Date	Test	Results	Date	Test	Results	
		/ /		/ /			/ /			/ /			
				/ /			/ /			/ /			
				/ /			/ /			/ /			

Medical Examination الفحص الطبي						Vaccination التطعيمات	Yes / No	
Organ	Normal	Abnormal	Organ	Normal	Abnormal			
General			Breast			T.T.	☐	☐
Head & Neck			Lung			Others	☐	☐
Heart			Abdomen			If yes: Specify: ----------		
			Lower limbs					
Date:	/ /		Doctor's Signature:					

Height:

التاريخ Date	ضغط الدم BP	الاوزما Oedema	الوزن Weight	فحص البول Urine		دقات قلب الجنين FHS		عمر الحمل Gestational age		المجيء Presentation C031	الشكوى والملاحظات وخطة العلاج Complaint , Management & Remarks	Supplements (iron +F.A)	الزيارة التالية Next visit	التوقيع Seen by
				زلال Alb	سكر Sug	+ve	-ve	بالحساب Date C008	بالحجم /سم Size /cm C009					

نموذج فحص الحوامل بالموجات فوق الصوتية
Antenatal Ultrasound Scan Examination

MCH/ VILIAGE CENTE		مركز رعاية / امومة
Governorate		المحافظة
File No.		رقم الملف
Personal Id No.		رقم الهوية الشخصية/ جواز السفر

LMD ---------- تاريخ آخر دورة شهرية
EDD ---------- التاريخ المتوقع للولادة

Personal Identification		التعريف الشخصي	
العائلة قبل الزواج Family Before Marriage	اسم العائلة Family Name	اسم الأب Father's Name	الاسم الأول First Name

Date of Birth — تاريخ الميلاد

اليوم Day	الشهر Month	السنة Year

Date	/ /	/ /	/ /	/ /
Gestational Age				
Fundal Height				

نموذج فحص الحوامل بالموجات فوق الصوتية
Antenatal Ultrasound Scan Examination

Date		/ /	/ /	/ /	/ /
Gestation (WK)					
No. of fetuses					
Heart activity					
Placenta					
Presentation					
Fetal sex					
Liquor	Quantity — To be removed				
	Deep pocket				
	AFI				
GS					
CRL					
BPD					
FL					
AC					
EGA					
EFW					
EDD					
Congenital anomalies					
Comment					
Recommendation					
Doctor's name					
Doctor's signature					

Paper 1

PLOS ONE

RESEARCH ARTICLE

Comparing individual-level clinical data from antenatal records with routine health information systems indicators for antenatal care in the West Bank: A cross-sectional study

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Data Availability Statement: The dataset used in the analyses was obtained with prior approvals from the Ministry of Health, Palestine, and are not publicly available. The definitions and inclusion criteria for the data are, however, documented at the Palestinian National Institute of Public Health as to reproduce the identical data, and are available with permission from the Ministry of Health, Palestine. The authors confirm they accessed the data used in their study in the same manner they

Abstract

Background

In most low- and middle-income settings, national aggregate health data is the most consistently available source for policy-making and international comparisons. In the West Bank, the paper-based health information system with manual aggregations is transitioning to an individual-level data eRegistry for maternal and child health at the point-of-care. The aim of this study was to explore beforehand how routine health information systems indicators for antenatal care can change with the introduction of the eRegistry.

Methods

Data were collected from clinical antenatal paper records of pregnancy enrollments for 2015 from 17 primary healthcare clinics, selected by probability sampling from five districts in the West Bank. We used the individual-level data from clinical records to generate routinely reported health systems indicators. We weighted the data to produce population-level estimates, and compared these indicators with aggregate routine health information systems reports.

Results

Antenatal anemia screening at 36 weeks was 20% according to the clinical records data, compared to 52% in the routine reports. The clinical records data showed considerably higher incidences of key maternal conditions compared to the routine reports, including fundal height discrepancy (20% vs. 0.01%); Rh-negative blood group (6.8% vs. 1.4%); anemia with hemoglobin<9.5 g/dl (6% vs. 0.6%); and malpresentation at term (1.3% vs. 0.03%). Only about a sixth of cases with these conditions were referred according to guidelines to designated referral clinics.

expect future researchers to do so, and did not receive special privileges from the Ministry of Health, Palestine.

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Competing interests: The authors have declared that no competing interests exist.

Conclusions

Differences between indicators from the clinical records data and routine health information systems reports can be attributed to human error, inconsistent denominators, and complexities of data processes. Key health systems indicators were prone to underestimations since their registration was dependent on referral of pregnant women. With a transition to individual-level data, as in the eRegistry under implementation, the public health authorities will be able to generate reliable health systems indicators reflective of the population's health status.

2 Introduction

The monitoring of global progress in reproductive, maternal, newborn and child health hinges on the routine availability of good quality data [1–3]. Low and middle-income countries (LMIC) typically rely on common sources of data for decision-making, such as censuses and population-based surveys, and to a lesser extent on clinical records and other forms of provider-reported data [4, 5]. The majority of process indicators to assess the delivery of essential interventions in maternal and child health are not amenable to measurement solely through population-based surveys [6, 7]. Strengthening of routine data collections in health facilities is important, since these data may be the most suitable source for many maternal and child health indicators [8–10]. Globally, there has been a sustained call for improving the quality and availability of data from Routine Health Information Systems (RHIS) [11–14]. Despite this, RHIS data for maternal and child health are often lacking in most LMIC settings and if available are incorrect, incomplete or of poor quality [8, 15–17]. There are increasing efforts to improve health system-wide data collection in many LMIC with electronic health information systems, although most of these systems focus on collection of aggregated data [18]. Data aggregation, however, is fraught with its own issues, such as incorrect and inconsistent definitions of the indicators and denominators and errors in counting, and this is partly due to RHIS reporting processes and partly due to behavioral factors [19–23]. The indicators collected in RHIS seemingly have little direct consequence on delivery of health services and it is sometimes challenging to impart the importance of good quality routine data collection to the care providers [24–27].

The paper-based health information system at the primary healthcare level in the West Bank is now transitioning to an eRegistry for maternal and child health [25, 28, 29]. The eRegistry will in the future compute and automatically generate RHIS indicators from individual-level clinical data collected by care providers at the point-of-care in primary healthcare clinics, thus eliminating the need for manual aggregations and reporting [25].

The objective of this study was to compute routinely reported indicators from individual-level clinical data from antenatal paper records, mimicking an eRegistry, and compare these with indicators reported in the existing health information system in the West Bank.

3 Materials and methods

First, we selected indicators of antenatal care that were routinely reported in the health system in the West Bank. We used data from clinical records available from a cross-sectional sample of primary healthcare clinics to generate the selected indicators (Fig 1). These indicators were then compared with the indicator values in aggregate RHIS reports available at the clinic-, district- and national levels (Fig 1).

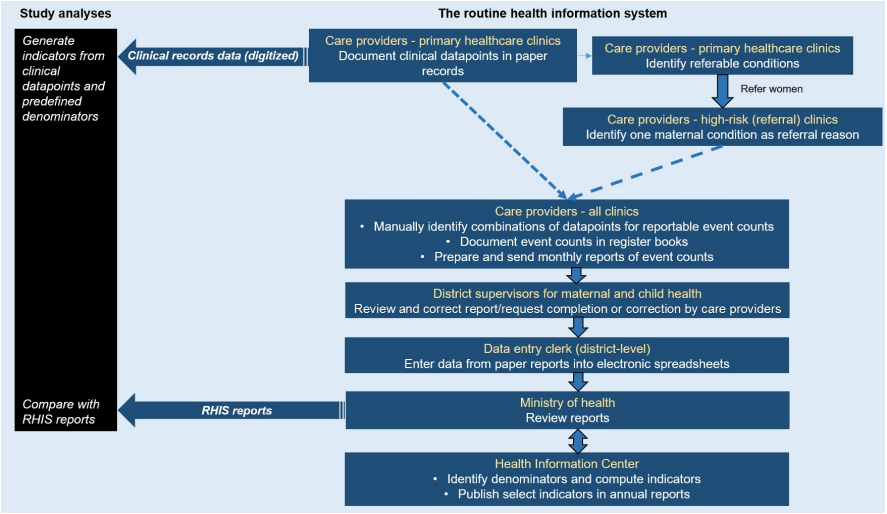

Fig 1. Aggregate reporting in the paper-based routine health information in the West Bank, Palestine, and sources of data used for analyses in this study.

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3.1 Study setting

In the West Bank, two types of healthcare facilities provide antenatal care in the public health system–primary healthcare clinics and referral clinics, also known as high-risk clinics [28]. According to the clinical guidelines in the public health system, when pregnant women are detected with certain conditions during antenatal care in the primary healthcare clinics, they are referred to pre-specified high-risk clinics [28].

In the paper-based RHIS in primary healthcare in the West Bank, care providers first document data in clinical records in the primary healthcare clinics. The clinical records used for antenatal care consist of socio-demographic data; obstetric, surgical and medical history; lab test results and ultrasound examinations. Using the clinical records, care providers manually identify and aggregate reportable conditions and events, and document the event counts in dedicated register books on a daily or weekly basis. Aggregate monthly reports of event counts are then prepared and sent from all primary healthcare clinics to the district-level, and subsequently to the national health authorities (Fig 1). The high-risk clinics, in addition, report on the number of maternal conditions observed in referred women who attend care, and submit aggregate reports on behalf of all primary healthcare clinics from which they receive referrals in each district (Fig 1). A select list of RHIS indicators are published annually as part of national health reports for the West Bank with statistics reported per district [30]. In the West Bank, obstetric services are only provided at the hospitals, but they do not report to the RHIS on maternal conditions that may have been identified during antenatal care.

In 2016, the first phase of the national implementation of the eRegistry was launched with the intention to include five districts in the West Bank [28, 29]. In preparation for the eRegistry implementation, data, equivalent to the planned data in the eRegistry, was extracted from paper-based clinical records for the year of 2015 in a random sample (see below) of primary healthcare clinics. According to an inventory assessment of the primary healthcare clinics in Palestine completed in

2014, these clinics enrolled about 11,400 pregnancies a year, an average of 70 pregnancies per clinic per year [28, 29]. These clinics referred to one of 9 high-risk clinics located in the five districts [28].

3.2 Sample size and sampling

Sample size estimations for data collection from the clinical records were made using 'OpenEpi' for a population size of 11,400, aiming to enable the detection of a frequency of 1% for the least prevalent outcome in the population (for example, severe anemia in pregnancy) with an absolute precision of 0.5% [31]. A minimum sample of 1344 clinical records was required, corresponding to all pregnancies registered over a year from 15–20 clinics.

Primary healthcare clinics were selected using the probability proportional to size method, in order to obtain a data set of pregnancies that was representative of the healthcare received by pregnant women in the West Bank [32]. Selection was continued until a minimum number of clinics was available to achieve the required sample size, provided the clinical records of all pregnant women enrolled over one year in the sampled clinics were included in the data collection.

3.3 Indicators

To enable the comparisons we selected antenatal care indicators that were routinely reported to the RHIS by the health system, and could be computed in an identical manner with data from clinical records (Table 1). We then ascertained the definitions, diagnostic classifications and data categorizations of the indicators as they are intended to be used for aggregate RHIS reporting. We excluded from our analyses those indicators that cannot be computed using datapoints from clinical records, such as antenatal supplementation of iron and folic acid that was reported in the RHIS as number of units prescribed. Conditions such as preterm rupture of membranes and antepartum vaginal bleeding were part of RHIS reporting, but were excluded since women with these conditions were most likely referred to hospitals and these data were, therefore, unlikely to be accurately collected in clinical records.

3.4 Data extraction

3.4.1 Clinical records data. Two trained nurse-midwives completed the data extraction during January–April 2017, and entered data from paper-based clinical records into electronic data entry forms hosted on the District Health Information System 2 (DHIS2) software platform [34]. Data from approximately 10% of all antenatal records were entered by both the data extractors, and these data were checked for quality and consistency [28, 29].

3.4.2 Aggregate RHIS reports. For the comparisons, RHIS reports of aggregate event counts and indicators were obtained from the Ministry of Health as electronic spreadsheets (Table 2). Event counts for three of the selected indicators were available in the RHIS reports sent from the primary healthcare clinics (RHIS clinic reports) (Table 2). Event counts of reportable maternal conditions were available at the district-level, and reported from the high-risk (referral) clinics (RHIS district reports) (Table 2). All the indicators were part of the publicly available RHIS national reports (nationally reported statistics for the five districts) (Table 2).

3.5 Analyses

3.5.1 Clinical records data. We used the clinical datapoints and definitions of indicators listed in Table 1 to reconstitute each of the selected indicators from the clinical records data. Gestational ages were computed from the first day of the woman's last menstrual period, according to usual clinical practice in this context. If these data were missing, the ultrasound estimated expected date of delivery was used to calculate gestational ages. We calculated

Table 1. Routinely reported indicators of antenatal care in the RHIS selected for analysis–definitions and data needs for computation from clinical records data.

Serial number	RHIS indicator included in analyses	Definition for computation of event counts (numerators)	Datapoints from clinical records for computations
1.	Antenatal visits (mean)	Total number of antenatal visits, total number of pregnancies enrolled	
2.	Maternal age	Age of woman at the time of registration of pregnancy*	Date of birth of the pregnant woman; date of first antenatal visit
3.	Anemia: maternal anemia at 36 weeks	Pregnant women who have Hb less than 11 g/dl at 35–38 gestational weeks	Lab test: Hb (g/dl); gestational age[ɬ]
4.	Reportable maternal conditions from referrals		
4.1	Gestational diabetes mellitus	Women with a random blood sugar > = 140 g/dl or a 1 hour 50 g oral glucose challenge test of > = 140 mg/dl	Lab test: random blood sugar, oral glucose challenge test
4.2	Multiple pregnancy	Women with multiple pregnancy	Ultrasound examination: number of fetuses
4.3	Malpresentation at term	Non-cephalic presentations at or after 36 gestational weeks	Ultrasound examination: fetal presentation; gestational age[ɬ]
4.4	Recurrent miscarriage	Three consecutive pregnancy losses prior to 20 gestational weeks	Obstetric history: 3 or more consecutive pregnancy losses prior to 20 gestational weeks
4.5	Preeclampsia[1] [33]	New onset hypertension plus new onset proteinuria after 20 weeks of gestation; hypertension defined as a systolic blood pressure of 140 mm Hg or greater, and/or a diastolic blood pressure of 90 mm Hg or greater	Clinical examination: systolic and diastolic blood pressures (mm Hg); lab test: proteinuria; gestational age[ɬ]
4.6	History of Cesarean sections	Cesarean section(s) in the previous delivery(ies)	Obstetric history: previous delivery/ies by Cesarean section
4.7	Anemia: at any gestational age	Pregnant women who ever have a Hb<9.5 g/dl	Lab test: Hb (g/dl); gestational age[ɬ]
4.8	Rhesus negative blood group	Pregnant women with a Rhesus negative blood group	Lab test: Rhesus typing of blood group
4.9	Fundal height discrepancy	A symphysis fundus height measurement of more or less than 2 cm compared to gestational age (in weeks) at the time of measurement	Clinical examination: symphysis fundus height values; gestational age[ɬ]
4.10	Oligohydramnios or polyhydramnios	Pregnant women with an ultrasound-detected increase or decrease in amniotic fluid	Ultrasound examination: diagnosis of oligohydramnios or polyhydramnios**

RHIS: Routine Health Information System; Hb: Hemoglobin

[1]American College of Obstetricians and Gynecologists. Task Force of Hypertension in Pregnancy.

[ɬ] Best estimate of gestational age computed from the dates of visits/ lab tests and date of last menstrual period, or from ultrasound estimated expected date of delivery.

*Categorized as <16 and >40 years according to the reporting requirement in the RHIS.

**No defined diagnostic criteria, subject to clinical diagnosis.

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prevalence of reportable maternal conditions in the entire sample as well as the occurrence of maternal conditions only among referred women. The latter was similar to how these indicators were generated as part of the aggregate RHIS reporting. Only test or examination results were documented in the paper records, and "no data" in these data fields were interpreted as a test or examination not performed.

Sample weights were added such that pregnant women from smaller clinics were assigned higher weights than those from larger clinics (the inverse of the probability of the clinic being selected, as to create data that can be compared to the RHIS district reports) [35]. Analyses were carried out using STATA version 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC), and the STATA command svyset was used to calculate weighted proportions and 95% confidence intervals (CI) [36].

3.5.2 Aggregate RHIS reports. Event counts from the aggregate RHIS reports were transformed to proportions with 95% confidence intervals using pre-defined denominators (Table 2).

Table 2. Data sources used for comparative analyses and their descriptions. *

Name of data source used in the study	Generated from	Sample for analyses and comparison	Data content	Indicators available/ generated	Denominator used for computing indicators in the study
Clinical records data	Primary healthcare clinics	Clinical paper records from probability sample of 17 clinics, cross-sectional data	Clinical datapoints	All	All pregnant women registered for antenatal care from 17 primary healthcare clinics, whose clinical records were extracted (n = 1369)
RHIS clinic reports	Primary healthcare clinics	Aggregate RHIS reports from 17 clinics	Event counts	Maternal age, antenatal visits, anemia at 36 weeks	Number of pregnancies enrolled as reported by care providers (n = 1463)
RHIS district reports	High-risk (referral) clinics	Aggregate RHIS reports from 9 high-risk clinics	Event counts	Maternal conditions from referrals	Pregnancies enrolled in clinics that refer to the high-risk clinics in the study area¥ (n = 11,416)
Nationally reported statistics	Health Annual Report [30]	Aggregate RHIS reports of national statistics**	Event counts; proportion indicators ''	All	Pregnancies enrolled in clinics in study- and non-study areas (n = 14,544)

RHIS: Routine Health Information System; Hb: Hemoglobin

*all data and indicators are for the year 2015 for 5 districts in the West Bank, Palestine.

¥ refers to the area in the five districts from where the sample for this study was derived.

**contains values of all event counts/indicators sent from primary healthcare clinics and high-risk (referral) clinics as part of the RHIS.

''anemia at 36 weeks published as a percentage of total hemoglobin tests with value <11g/dl, of all hemoglobin tests reported.

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3.6 Ethics approval

Ethical clearance was obtained from the Palestinian Health Research Council (PHRC/HC/272/17) and the Regional Committee for Medical and Health Research Ethics in Norway (2017/1537-3). We adhered to the Palestinian Ministry of Health's legal framework in obtaining access to anonymized data for secondary analyses [29].

4 Results

Seventeen primary healthcare clinics from 5 districts in the West Bank were included in the data collection and data from clinical records were available for 1369 pregnancies enrolled for antenatal care in 2015 in these clinics. Of these, 501 women (37%) were nulliparous. Sixteen-per-cent (n = 222) of the women were <20 years of age and 9% (n = 118) were >35 years age at the time of enrollment at the clinic. Complete RHIS clinic reports for 2015 were obtained from all the primary healthcare clinics that were included in the data collection of the clinical records (n = 17) (Table 2). RHIS district reports were available from all their corresponding high-risk clinics (n = 9) (Table 2).

4.1 Maternal age

There was consistency in the indicator maternal age at pregnancy registration between the clinical records data (age<16 years: 0.1%, 95% CI: 0–0.4; age>40 years: 1.2%, 95% CI: 0.6–2.1), RHIS clinic reports (age<16 years: 0.1%, 95% CI: 0–0.4; age>40 years: 1.4%, 95% CI: 1–2), and the nationally reported statistics for the five districts (age<16 years: 0.2%, 95% CI: 0.1–0.3; age>40 years: 1.7%, 95% CI: 1.5–2).

4.2 Antenatal visits

The number of antenatal visits per pregnant woman in the clinical records data (mean = 4.5; standard deviation = 2.3), RHIS clinic reports (mean = 4.5) and nationally reported statistics for the five districts (mean = 4.7) were all comparable.

4.3 Anemia at 36 weeks

The proportion of women with anemia at 36 weeks in the clinical records data (32%, 95% CI: 22–44) was similar to the RHIS clinic reports (31%, 95% CI: 29–35) and the nationally reported statistics for the five districts (30%, 95% CI: 29–31). However, there were 280 documented hemoglobin tests at 36 weeks in the clinical records data, representing a 20% anemia screening coverage at 36 weeks, compared to 890 reports of such hemoglobin tests (61% screening coverage) in the RHIS clinic reports. According to the nationally reported statistics for the five districts, there were 7602 hemoglobin tests at 36 weeks (52% screening coverage).

4.4 Reportable maternal conditions

In the clinical records data, the incidences of malpresentation at term (1.3%; 95% CI: 0.6–2.8), anemia (hemoglobin<9.5 g/dl) (6%, 95% CI: 4.1–8.7), Rh-negative blood group (6.8% 95% CI: 4.5–10.2) and fundal height discrepancy (20%; 95% CI: 12.4–30.8) were higher compared to the incidence of these reportable conditions for referral in the RHIS district reports and nationally reported statistics for the five districts (Table 3). In the clinical records data, 7% (95% CI: 6–9) of the women had two and 1% (95% CI: 0.5–2) had three of the reportable maternal conditions.

According to the clinical records data, the proportion of women with a documented referral from the primary healthcare clinics to any health facility, ranged from 16% for fundal height discrepancy to 71% for preeclampsia (Fig 2). Proportions that were referred to the pre-specified high-risk clinic for reportable maternal conditions were lower (Fig 2).

Table 3. Routinely reported maternal conditions from antenatal care–comparison of indicators from all clinical records data and only referred women, and aggregate RHIS reports.

Reportable condition	Clinical records data—all* (N = 1369)		Clinical records data—occurrence of condition and referred**	RHIS district reports (N = 11,416)		RHIS national statistics (N = 14,544)	
	n	Weighted % (95% CI)	Weighted % (95% CI)	n	% (95% CI)	n	% (95% CI)
Gestational diabetes mellitus	12	0.8 (0.4–1.7)	0.05 (0.01–0.4)	79	0.7 (0.6–0.9)	79	0.5 (0.4–0.7)
Multi-fetal pregnancy	20	1.3 (0.8–2.0)	0.4 (0.2–1.0)	84	0.7 (0.6–0.9)	97	0.7 (0.5–0.8)
Malpresentation at term	20	1.3 (0.6–2.8)	0.2 (0.1–0.7)	2	0.02 (0–0.06)	4	0.03 (0.01–0.07)
Recurrent miscarriages	26	1.7 (0.9–3.5)	0.7 (0.2–2.4)	144	1.3 (1.1–1.5)	150	1.0 (0.2–3.0)
Preeclampsia	7	0.6 (0.2–1.3)	0.2 (0.02–1.2)	26	0.2 (0.1–0.3)	31	0.2 (0.1–0.3)
History of Cesarean sections	93	6.4 (4.1–9.7)	2.2 (1.3–3.6)	631	5.5 (5.1–5.9)	777	5.3 (4.9–5.7)
Anemia (Hb<9.5 g/dl)	88	6.0 (4.1–8.7)	0.9 (0.4–2.0)	87	0.8 (0.6–0.9)	93	0.6 (0.5–0.8)
Rh-negative blood group	95	6.8 (4.5–10.2)	1.2 (0.6–2.1)	180	1.6 (1.4–1.8)	202	1.4 (1.2–1.5)
Fundal height discrepancy	253	20 (12.4–30.8)	0.9 (0.5–1.6)	None	None	1	0.01 (0–0.04)

RHIS: Routine Health Information Systems; CI- confidence interval; Hb- hemoglobin

*No cases of oligohydramnios or polyhydramnios in the clinical data

**Estimates of indicators after accounting for missed data in the RHIS reporting from women not being referred according to guidelines

https://doi.org/10.1371/journal.pone.0207813.t003

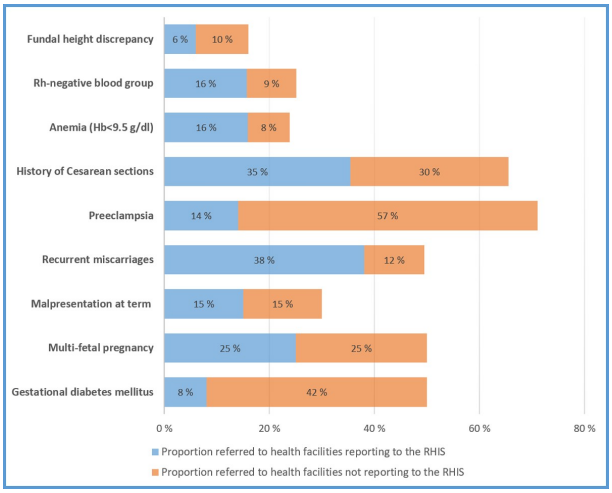

Fig 2. Women with maternal conditions that were referred to health facilities that report to the RHIS, and to health facilities that do not report on antenatal care indicators to the RHIS. RHIS: Routine health information system.

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If reportable maternal conditions were estimated only among pregnant women that were referred to high-risk clinics, malpresentation at term (0.2%, 95% CI: 0.1–0.7) and fundal height discrepancy (0.9%, 95% CI: 0.05–1.7) were the only two conditions that continued to have a higher value in the clinical records data compared to RHIS reports (Table 3).

For all routinely reported aggregate RHIS indicators of antenatal care, there was consistency between what was reported by the primary healthcare clinics (RHIS clinic reports) and high-risk clinics (RHIS district reports), and the publicly available national reports (Table 3).

5 Discussion

Appraisal of RHIS data and indicators are important components of assessment of health systems [37, 38]. In this study, we compared RHIS reports with individual-level data from clinical records, which revealed important pitfalls in the generation of the indicators, and these would have been missed by only performing consistency checks of reports within the existing RHIS. The divergences between the clinical records data and RHIS reports were due to previously recognized issues with RHIS in general, such as inconsistent denominators for calculating indicators, errors in manual computations, and production of unreliable indicators due to a complex reporting structure in the health system [17, 26, 39].

RHIS reporting of maternal anemia at 36 weeks was an illustration of an indicator with an inconsistent denominator. Apart from reporting an overall higher number of hemoglobin tests at 36 weeks compared to the clinical records data, three out of the 17 primary healthcare clinics reported more hemoglobin tests than the total number of pregnancies enrolled in 2015, and appeared to be including hemoglobin tests of pregnancies enrolled in the previous year. With the denominator reported and used in the RHIS for maternal anemia, it was neither feasible to estimate the true incidence of maternal anemia for a given year of reporting nor quantify the coverage of hemoglobin testing.

In our study, issues with manual computations were particularly evident for the indicator fundal height discrepancy. The gestational ages documented by the care providers often varied from the gestational ages generated for this study. While some care providers may have determined fundal height discrepancy based on the current exact gestational age, others may have used the nearest completed gestational week. For example, a gestational age of 30 weeks and three days may be interpreted as 30 weeks or 31 weeks. Using the gestational ages documented by the care providers for computing this indicator from the data in the clinical records yielded an incidence of fundal height discrepancy of 9% (95% CI: 4–19), which was still higher than the RHIS reports (0.01%, 95% CI: 0–0.04). Additional reasons for the observed difference between the clinical records data and RHIS reports for this indicator include the lack of more comprehensive fetal growth monitoring strategies, non-compliance to guidelines to refer women with any fundal height discrepancy as per the existing definition, and known issues in the measurement itself [40–42]. Ultrasound examinations during antenatal care are reportedly widely used in the West Bank. Given this, ultrasound-based fetal growth monitoring may take precedence over serial fundal height measures. However, there were neither diagnostic standards nor reporting guidelines for results from other forms of screening of fetal growth.

Three factors relating to a complex RHIS reporting process contributed to the disparity in the reportable maternal conditions between the clinical records data and RHIS reports. First, maternal morbidities (except maternal anemia at 36 weeks) were reported from the high-risk clinics and not from the referring primary healthcare clinics, making the registration of the indicators conditional on referral and utilization of care. However, there was low compliance of the primary healthcare clinics to the recommended guidelines for referrals to high-risk clinics (Fig 1). Second, in the RHIS district reports, only one reportable maternal condition was registered per referred pregnant woman. Third, there were notable variations among the districts in the selection of the principal maternal condition for reporting to the RHIS. In one of the 5 districts, history of Caesarean sections constituted 26% of all the reported maternal conditions and gestational diabetes mellitus 9%. In another district, 55% of all the reporting was for history of Cesarean sections, with gestational diabetes mellitus constituting less than 1%.

Similarly, there may be variations in referral practices among the primary healthcare clinics. In the clinical records data from the sample of clinics included in this study, a lower proportion of women with history of Cesarean sections (2.2% vs. 5.3%) and gestational diabetes mellitus (0.05% vs. 0.5%) were referred to the high-risk clinics, compared to RHIS reports.

Other studies in the West Bank have reported Cesarean section rates of at least 14–23% [30, 43]. The proportions of women with history of Cesarean sections from the clinical records data as well as RHIS reports were clear underestimations, probably due to incomplete documentation of this datapoint in the clinical records.

The generalizability of all RHIS indicators can be improved by adopting more standardized definitions. As an illustration, if the World Health Organization's diagnostic cut-off for fasting blood sugar levels was used for computations of the clinical records data, the resulting incidence of gestational diabetes mellitus was 6% (95% CI: 4–10), compared to the 0.8% (95% CI: 0.4–1.7) obtained from the clinical records data using the current definition in the public health system [44].

The reporting of the mean number of antenatal visits is not representative of antenatal care coverage for an individual. The variability in antenatal visits for individual pregnant women was evident from the wide standard deviation (SD = 2.3) around the mean.

A strength of this study was its ability to identify issues beyond the quality of RHIS data and processes, such as variations in adherence to guidelines for referrals as well as selective reporting of indicators in the health system. The quality of healthcare services may be improved by understanding and addressing issues related to referrals. The public health authorities may

need to revisit the value of certain guidelines for referral, particularly for non-critical conditions during pregnancy. The feasibility and effectiveness of different fetal growth monitoring strategies in primary healthcare for this population are themes for future research. One of the functionalities of the eRegistry, the interactive checklists and clinical decision support, provides guideline-based recommendations for referral and clinical reminders for the care providers at the point-of-care in the primary healthcare clinics [28].

One limitation of this study is that only data that were documented in the antenatal records were considered in the analyses. We have regarded any undocumented visits or tests as not having occurred. Some primary healthcare clinics may have additional or alternative sources of documentation that are used specifically for the purpose of RHIS reporting, particularly for lab test results (for example, for reporting of maternal anemia at 36 weeks). Lack of exclusive use of clinical records for all documentation by the care providers may also explain the differences in the number of new enrollments of pregnancies from the clinical records data (n = 1369) and RHIS reports (n = 1463). About 50% of all pregnant women in the West Bank receive antenatal care in the private and non-governmental sector that are not part of RHIS reporting for antenatal care, and the incidences of maternal conditions reported in this study may not be representative of the entire population of the West Bank.

6 Conclusion

The eRegistry for maternal and child health aims to eliminate sources of errors that impact the quality of health systems data, by using individual-level clinical data to directly produce RHIS reports at the individual, clinic, sub-national and national levels. As the health system in the West Bank shifts from manually aggregated data to the eRegistry, it will be possible to generate more reliable and complete health systems indicators.

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Paper 2

PLOS ONE

RESEARCH ARTICLE

Effective coverage of essential antenatal care interventions: A cross-sectional study of public primary healthcare clinics in the West Bank

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Data Availability Statement: All results and the data used for analyses are presented in the manuscript and its supporting information files. Data cannot be shared publicly because of the limitations in scope that is part of our agreement with the data owners, the Palestinian Ministry of Health. The richness of individual-level data makes it possible to address a number of unrelated research questions from this material, which have not been approved by Palestinian research ethics authorities or the data owner. Access to data

Abstract

Background

The proportion of women attending four or more antenatal care (ANC) visits is widely used for monitoring, but provides limited information on quality of care. Effective coverage metrics, assessing if ANC interventions are completely delivered, can identify critical gaps in healthcare service delivery. We aimed to measure coverage of at least one screening and effective coverage of ANC interventions in the public health system in the West Bank, Palestine, and to explore associations between infrastructure-related and maternal sociodemographic variables and effective coverage.

Methods

We used data from paper-based clinical records of 1369 pregnant women attending ANC in 17 primary healthcare clinics. Infrastructure-related variables were derived from a 2014 national inventory assessment of clinics. Sample size calculations were made to detect effective coverage ranging 40–60% with a 2–3% margin of error, clinics were selected by probability sampling. We calculated inverse probability weighted percentages of: effective coverage of appropriate number and timing of screenings of ANC interventions; and coverage of at least one screening.

Results

Coverage of one screening and effective coverage of ANC interventions were notably different for screening for: hypertension (98% vs. 10%); fetal growth abnormalities (66% vs. 6%); anemia (93% vs. 14%); gestational diabetes (93% vs. 34%), and antenatal ultrasound (74% vs. 24%). Clinics with a laboratory and ultrasound generally performed better in terms of effective coverage, and maternal sociodemographic factors had no associations with

requires ethical clearance by the Palestinian Health Research Council, or any institutional review board approved by the Ministry of Health, as well as approval from the Ministry of Health. Data are available from the Palestinian National Institute of Public Health. Detailed descriptions to re-create identical data, as well as contact addresses to the data source, are available as supporting information.

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effective coverage estimates. Only 13% of the women attended ANC visits according to the recommended national schedule, driving effective coverage down.

Conclusion

Indicators for ANC monitoring and their definitions can have important consequences for quantifying health system performance and identifying issues with care provision. To achieve more effective coverage in public primary care clinics in the West Bank, efforts should be made to improve care provision according to prescribed guidelines.

Introduction

Antenatal care (ANC) provides an opportunity to detect risk factors, prevent complications and improve birth preparedness of pregnant women in order to reduce maternal and neonatal morbidity [1, 2]. The proportion of women who attend four or more ANC visits (ANC 4+), is used extensively as an indicator for monitoring health of pregnant women as well as health system performance [3, 4]. However, measuring contact of pregnant women with the health system has limitations, since attending an ANC visit does not imply that pregnant women receive good quality care [5–7]. The quality of care received may also be inequitable. In low and middle-income countries (LMIC), even with high levels of ANC 4+, wealthier and better-educated women are significantly more likely to receive quality care [8].

Effective coverage, in contrast, combines utilization of healthcare services with the quality of care received. Conceptually, effective coverage is "the proportion of the population who need a service that receive it with sufficient quality for it to be effective" [9]. For ANC, effective coverage is conventionally comprised of 'ANC attendance', defined as having at least one or at least four ANC visits; and 'quality', assessed in terms of ANC content [10]. Standard ANC content includes a set of interventions, which entail single, two-step or repeat screening tests and managements at specified times during pregnancy [11, 12]. The World Health Organization has published widely accepted recommendations for ANC [13], including suggestions for appropriate contact (frequency and timing between clients and the health system) and content (screening and management) based on evidence of effectiveness [14, 15].

Whether pregnant women have received some or all components of a set of interventions as part of ANC at least once during pregnancy has been used to indicate quality of care [9, 16, 17]. This measure, without timing or frequency, is not adequate to measure effectiveness or quality of care provided. For example, one hemoglobin measurement in pregnancy does not correspond to the provision of effective interventions for prevention and management of anemia as recommended by the WHO guidelines–being tested only late in pregnancy excludes the opportunity for treatment, and being tested only early does not imply a safe hemoglobin level at delivery. Measuring effective coverage of essential ANC interventions is, therefore, more comprehensive than ANC4+ for assessing ANC service provision [10].

Assessing effective coverage can help identify critical 'bottlenecks' around provision of healthcare such as care providers' knowledge of clinical practice guidelines and infrastructure availability [18, 19]. Typical health systems 'bottlenecks', which limit its capacity to provide effective care, include access to care, availability of trained human resources and health infrastructure as well as utilization [20]. Studies assessing ANC content and quality in LMIC often use population-based surveys as the main data source. In general, household surveys provide limited information on processes of care and the accuracy of information collected is reliant

on recall of survey participants [21]. Facility-based documentation and direct observations [22] can be used to assess effective coverage of ANC interventions at a given visit. Facility-based data, if available routinely over a period of time, can provide information on the number and timing of screening tests of ANC interventions provided–aspects of healthcare provision not available from household surveys [23, 24].

Better health information systems and improving the quality of healthcare services are of high priority for the Palestinian health system [25, 26], with no published studies of health system performance or ANC provision in public primary healthcare clinics in the West Bank available. In the West Bank, maternal and child health services are organized in two tiers–primary healthcare where ANC, postpartum care and newborn care are provided; and secondary or tertiary healthcare where obstetric services are provided. The public sector is reportedly the single largest provider of ANC, catering to almost 50% of all women that give birth in a year [27]. Based on place of residence, pregnant women are assigned to a governmental primary healthcare clinic for care. ANC is also provided by private health facilities, non-governmental organizations and the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) [27]. A recent household survey suggests that more than 95% of women attend 4 or more ANC visits [28]. The Palestinian Ministry of Health and the Palestinian National Institute of Public Health are currently implementing an electronic health information system for maternal and child health consisting of individual-level data collected at the point-of-care (eRegistry) in public primary healthcare clinics [29]. As a result of this implementation, the existing data ecosystem for maternal and child health is shifting from aggregated data on the mean number of ANC visits per pregnant woman to individual-level data with accessible information on content and processes of ANC service delivery. Such a transition could be disruptive to the health system if the nature and magnitude of any changes to the available data and indicators, and associated factors are not anticipated or not understood by health system managers.

In this study, our objective was to assess the coverage of at least one screening and appropriate number of screenings of ANC interventions, and effective coverage of ANC interventions in public primary healthcare clinics in the West Bank, Palestine. Secondarily, we explored selected infrastructure-related and maternal sociodemographic factors potentially associated with effective coverage.

Materials and methods

We extracted data from paper-based clinical records of antenatal care to demonstrate the potential changes in health and health systems performance indicators that would be observed when transitioning from the existing aggregate health information system to the eRegistry. Since the Palestinian national eRegistry implementation was rolled out in phases, we extracted records from a random cross-sectional sample of clinics in the five districts that comprised phase one, from the year 2015, before any clinics started using the eRegistry.

Study setting

ANC records (paper-based until 2016 and the eRegistry thereafter) are primarily used for clinical documentation in all primary healthcare clinics. Paper-based ANC records were structured data entry forms consisting of data elements pertaining to clients' medical history, screening tests results, clinical examinations, and clinical managements [29]. While nurses or midwives typically provide routine ANC in primary healthcare clinics, doctors visit the clinic once or twice a week and perform clinical and ultrasound examinations and interpret lab test results,

and manage complications in pregnancies. Clinics may either have their own laboratory and ultrasound or share these facilities with other clinics.

Sample size and sampling

A single data collection exercise was set up to measure maternal morbidity rates [30] as well as effective coverage of ANC interventions. The overall sample size was determined by the least prevalent outcome expected, corresponding to a 1% prevalence of severe anemia in pregnancy. It was assumed that effective coverage of ANC interventions would be in the 40–60% range (based on expert opinion in the absence of relevant data). In order to estimate indicators in these ranges that were representative of the five phase 1 districts, and with margins of error of 2–3% for the coverage of ANC interventions and 0.5% for maternal morbidity rates, 1344 pregnancies were required [31]. OpenEpi was used for sample size calculations [31].

Primary healthcare clinics were selected by probability sampling proportional to clinic size until a sufficient number of clinics was sampled to achieve the calculated sample size (n = 1344), provided that clinical records of all women registered for ANC in these clinics during January–December 2015 were included in the data collection. Since the primary healthcare clinics were selected by unequal probability sampling, inverse probability sample weights were assigned to individual pregnancies in order to produce results that were more generalizable to the five districts included in the data collection, and to produce robust standard errors [32]. The same dataset was used for the calculation of prevalences of maternal health conditions and details are presented elsewhere [30].

Data collection

Data were extracted from paper-based ANC records and entered into electronic forms on the District Health Information System 2 (DHIS2) software, which were identical to the data capture forms of the eRegistry, to ensure similar data structures [33]. Two trained data collectors, who were nurse-midwives, extracted data from clinical records. Ten per cent of the clinical records were extracted and entered twice by each of the data collectors and the study team carried out consistency checks of the double-entered data [34].

An inventory assessment of all public primary healthcare clinics in the West Bank was completed by the study team at the Palestinian National Institute of Public Health in December 2014. Information needed to support the implementation of the eRegistry was collected, including details of infrastructure in the clinics, laboratory and ultrasound availability, and the number and type of care providers for maternal and child health [29, 34]. Clinic staff were asked to return completed assessment forms to the study team; 100% of clinics completed this form.

Outcome variables

ANC interventions included in our analyses comprised those that were: 1) recommended as part of routine ANC content in the public health system in the West Bank; 2) applicable to all pregnant women irrespective of risk status; and 3) amenable to measurement using data from ANC records. Applying these criteria, eight ANC interventions were selected (Table 1). Three of these interventions were similar to the WHO Essential interventions [35], and four of the interventions were recommended as part of the WHO ANC model for a positive pregnancy experience [13] (Table 1). Six additional ANC interventions recommended in the public health system were excluded from this analysis, either because the ANC records did not contain the variables required to generate the indicators or because the interventions were not appropriate for the primary healthcare level (S1 Text).

Table 1. Recommended schedule of ANC visits and ANC interventions in the West Bank.

ANC interventions	Recommended ANC visits schedule				
	Booking[ǂǂ]	16 weeks	24–28 weeks	32 weeks	36 weeks
Screening for hypertension[*]	X	X	X	X	X
SFH measurement[¥]	X	X	X	X	X
Screening for anemia[*]	X		X		X
Antenatal ultrasound[$]	X		X		X
Screening for gestational diabetes mellitus[¥]	X (Urine)		X (Blood)		
Screening for asymptomatic bacteriuria[¥]	X				
Screening for Rh-type[¥]	X				
Screening for tetanus immunization status[*]	X				

[*]Similar to the WHO's Essential Interventions for RMNCH

[¥]Recommended in the 2016 WHO ANC model for a positive pregnancy experience

[$]Context-specific recommendation

[ǂǂ]Booking: refers to first antenatal visit at the clinic; ANC: Antenatal care; SFH: Symphysis-fundal height.

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For each ANC intervention selected, we defined indicators of coverage of at least one screening test, coverage of appropriate number of screenings (only applicable to ANC interventions requiring repeat or two-step screening), and effective coverage, based on ANC guideline in the West Bank (Table 2). Definitions for effective coverage of ANC interventions included both the recommended timing and number of screening tests of the intervention (Table 2).

In the definitions for effective coverage of ANC interventions, the appropriate number of timely screening tests were adjusted according to the gestational age of pregnant women at

Table 2. Definitions of indicators of coverage of at least one screening, coverage of appropriate number of screenings, and effective coverage of ANC interventions.

ANC intervention	Coverage of at least 1 screening	Coverage of the appropriate number of screening	Effective coverage (appropriate number and timing of screenings)
Screening for hypertension	Proportion with at least one blood pressure measurement	Proportion with five blood pressure measurements	Proportion with blood pressure measurements at all recommended ANC visits
SFH measurement	Proportion with at least one SFH measurement	Proportion with five SFH measurements	Proportion with SFH measured at all recommended ANC visits[ǂ]
Screening for anemia	Proportion with at least one hemoglobin test	Proportion with three hemoglobin tests	Proportion with hemoglobin tests at booking[ǂǂ], 24–28 and 36 weeks[*]
Antenatal ultrasound	Proportion with at least one ultrasound examination	Proportion with three ultrasound examinations	Proportion with ultrasound examinations at booking[ǂǂ], 24–28 and 36 weeks[*]
Screening for gestational diabetes mellitus	Proportion with either urine sugar or blood sugar test	Proportion with both urine sugar and blood sugar test	Proportion with urine sugar test at booking[ǂǂ] and blood sugar test at 24–28 weeks[*]
Screening for asymptomatic bacteriuria	Proportion with urine microscopy test		Proportion with urine microscopy test at booking[ǂǂ]
Screening for Rh-type	Proportion with Rh-typing		Proportion with Rh-typing at booking visit
Screening for tetanus immunization status	Proportion whose tetanus immunization status is checked by asking for history of immunization or reviewing immunization record		Proportion whose tetanus immunization is checked by asking for history of immunization or reviewing immunization record at booking[ǂǂ]

[ǂ]calculated for ANC visits that occur after 16 weeks

[*]given that registration of pregnancy was before the recommended timing of screening

[ǂǂ]Booking: refers to first antenatal visit at the clinic.

ANC: Antenatal care; SFH: Symphysis-fundal height

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registration for ANC. For example, women who were registered for ANC before 24 gestational weeks were considered effectively screened for anemia if they had three hemoglobin tests–at first ANC visit, at 24–28 weeks and 36 weeks (Table 2), while women that were registered for ANC after 28 weeks were considered effectively screened if they received two hemoglobin tests, one at their first ANC visit and another at 36 weeks (Table 2).

We calculated the proportion of women with any four and any five ANC visits irrespective of timing of visits. Since coverage of appropriate number of screening tests and effective coverage are influenced by attendance rates following pregnancy registration, we calculated the proportion attending all timely visits appropriate to when the first ANC visit occurs. We measured the proportion of women attending ANC visits in the specific time windows where interventions were recommended (Table 1). We also assessed the proportion attending all 5 timely visits including an early first ANC visit before 14 weeks.

Variables potentially associated with effective coverage

Laboratory and ultrasound availability were the infrastructure-related factors chosen for analyses, since these were expected to be associated with effective coverage. Clinics were grouped into those that had all relevant infrastructure and those that had one or more missing infrastructure. Since the sample of clinics had similar cadres of care providers, and were expected to be similar in terms of availability of other infrastructure needed for ANC (e.g. sphygmomanometers), we did not use these for exploratory analyses.

Maternal sociodemographic variables used in the analyses were those available in the ANC records, including women's age at pregnancy registration, age at marriage, education and parity.

Data analyses

All analyses were done using STATA version 15 (StataCorp. 2015. *Stata Statistical Software*: *Release 14*. College Station, TX: StataCorp LP), using the command 'svyset' for generating weighted proportions and 95% confidence intervals (CI) [36]. Descriptive statistics were produced for the following variables and categories: women's age at pregnancy registration ($<$21 years, 21–34 years, $>$34 years); age at marriage ($<$20 years and $\geq$20 years); number of years of education of women ($<$10 years, 10–13 years, $>$13 years); and parity (nulliparous, multiparous$<$4, multiparous$\geq$4). These categories were pre-defined in the dataset obtained for this analysis in accordance with the data sharing policies outlined in the Standard Operating Procedures for routine registry operations [34].

Chi-square tests of differences were used for exploratory analyses of effective coverage of ANC interventions across sub-groups based on infrastructure-related and maternal sociodemographic variables. Adjusted odds ratios (OR) and 95% CI were generated for each of the interventions, through a logistic regression model consisting of infrastructure-related characteristics (laboratory and ultrasound availability) and all maternal sociodemographic variables (women's age at pregnancy registration, education, age at marriage and parity).

Ethics approval

Anonymous secondary data for analyses were obtained with approvals from the Palestinian Ministry of Health, in accordance with the data sharing principles outlined in the Standard Operating Procedures for routine registry operations [34]. Ethics approvals for this study were obtained from the Palestinian Health Research Council (PHRC/HC/272/17) and the Regional Committee for Medical and Health Research Ethics in Norway (2017/1537). Descriptions to

re-create identical data, as well as contact addresses to the data source, are available as supporting information (S2 Text).

Results

Data were collected from 1369 clinical records of pregnant women first registered for ANC in 2015 in 17 primary healthcare clinics. Totally, these women attended 6397 ANC visits during 2015 and 2016. One out of the 17 primary healthcare clinics had a non-nurse/midwife health worker that was the sole provider of ANC, while all other clinics had a nurse or midwife providing ANC. All 17 clinics had a doctor visiting once a week to provide ANC. Of the 17 primary healthcare clinics, six were equipped with both a laboratory and ultrasound. Two clinics each had either only a laboratory or only an ultrasound, while seven clinics had neither.

Fifty-four pregnancies in the sample (4%) ended in a documented spontaneous miscarriage. The mean gestational age at first ANC visit was 14 weeks (SD = 7), 47% of the women (95% CI: 38, 55, n = 638) attended their first ANC visit within 3 months and 67% of women (95% CI: 60, 73, n = 914) attended their first ANC visit within 4 months. The majority (75%) of women were between 21–35 years of age at the time of their first ANC visit, and 37% were nulliparous (Table 3).

ANC attendance

About half of the women attended at least five ANC visits, while 60% (95% CI: 50, 70) attended at least four ANC visits, when not considering the schedule or timing of visits (Table 4). Only 6% (95% CI: 5, 8) of the women attended all ANC visits according to the recommended ANC 5-visit schedule, including an early first ANC visit before 16 weeks. Disregarding early attendance and only considering the schedule of visits after pregnancy registration, 13% (95% CI: 9, 17) attended ANC visits as per the recommended national schedule (Table 4), and thus could have received complete hypertension and SFH screening.

The proportion of women attending all recommended ANC visits according to the national guidelines was higher in clinics with both laboratory and ultrasound (17%), compared to clinics with one or no such infrastructure (9%), with an adjusted OR of 2.0 (95% CI: 1.4, 2.8).

Table 3. Background sociodemographic characteristics of pregnant women in the sample.

Sociodemographic characteristics	Population (n)	Percentage
Age		
<20	222	16
21–35	1029	75
>35	118	9
Education		
<10	149	11
10–13	591	43
>13	514	37
Age at marriage		
<20	695	50
>20	573	42
Parity		
Nulliparous	501	37
Multiparous (<4)	666	48
Multiparous (≥4)	186	14

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Table 4. Comparison of coverage at least one screening of ANC intervention, coverage of appropriate number of screenings prescribed for ANC interventions, and effective coverage of ANC interventions (number and timing of screening of ANC interventions).

ANC intervention	Coverage of ANC interventions[$] (%, 95% CI)			ANC visits *(%, 95% CI)*	
	At least one screening test	Appropriate number of screening tests	Effective coverage	*Number of visits irrespective of timing*[‡]	*Appropriate number and timing of visits*[‡]
Screening for hypertension	**98 (96, 99)**	**38 (31, 47)**	**10 (8, 13)**	*48 (38, 58)*	*13 (9, 17)*
SFH measurement	**66 (50, 80)**	**35 (24, 48)**	**6 (4, 9)**		
Screening for anemia	**93 (89, 96)**	**31 (23, 40)**	**14 (9, 21)**	*73 (62, 81)*	*33 (26, 41)*
Antenatal ultrasound	**74 (59, 85)**	**43 (32, 54)**	**24 (18, 31)**		
Screening for gestational diabetes mellitus	**93 (88, 96)**	**69 (60, 77)**	**34 (26, 43)**	*85 (77, 90)*	*56 (50, 62)*
Screening for asymptomatic bacteriuria[*]	**55 (45, 64)**		**42 (36, 49)**[¥]	*NA*	
Screening for Rh-type[*]	**78 (67, 89)**		**64 (54, 73)**[¥]	*NA*	
Screening for tetanus immunization status[*]	**35 (23, 50)**			*NA*	

[$]refer Table 2 for definitions of coverage indicators of ANC interventions

[‡]refer Table 1 for number of ANC visits and their timing for each ANC intervention recommended in the national guidelines

[*]only one screening test during ANC is recommended in the national guidelines

[¥]refers to screening test provided during the first ANC visit.

ANC: Antenatal Care; SFH: Symphysis-fundal height; CI: Confidence Intervals

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Coverage of ANC interventions

Coverage of at least one sreening of ANC interventions ranged between 55% (95% CI: 45, 64) for screening for asymptomatic bacteriuria and 98% (95% CI: 96, 99) for hypertension screening (Table 4).

Compared to the coverage of at least one screening, coverage of the appropriate number of screenings was considerably lower for all interventions requiring repeat or two-step screening (Table 4). In clinics that had ultrasound equipment, coverage of any symphysis fundus height (SFH) measurement was 29%, while in clinics without ultrasound the coverage was 63%.

For diabetes screening, coverage of blood sugar test was 73% (95% CI: 65, 79) and urine sugar test was 89% (95% CI: 82, 94).

Effective coverage

Effective coverage of ANC interventions was lower than the coverage of at least one screening and coverage of appropriate number of screenings for all interventions except screening for tetanus immunization status (Table 4). Regarding screening for gestational diabetes mellitus, 43% (95% CI: 35, 52) had a blood sugar test at 24–28 weeks and 71% (95% CI: 63, 78) had a urine sugar test at booking visit.

Among those attending the prescribed number and timing of ANC visits (Table 4), the percentage receiving the relevant screening tests were as follows: hypertension screening: 77%, antenatal ultrasound: 73%, gestational diabetes: 61%, SFH measurement: 46% and anemia screening: 42%.

Effective coverage of six of the eight ANC interventions was highest in primary healthcare clinics with laboratory and ultrasound availability (Table 5). Clinics with a laboratory and ultrasound were associated with statistically significant higher odds of effectively screening for four ANC interventions. Screening for tetanus immunization status was the only ANC

Table 5. ANC interventions and infrastructure-related characteristics: effective coverage (%) and adjusted odds ratios from logistic regression analyses.

ANC interventions	Effective coverage (%)		Adjusted odds ratio (95% CI)[¥]
	One or more missing infrastructure (n = 728)	Both lab and ultrasound (n = 631)	
Screening for hypertension	7	14	2.2 (1.5, 3.1)
SFH measurement	7	4	0.6 (0.4, 1.0)
Screening for anemia	12	17	1.5 (1.1, 2.1)
Antenatal ultrasound	20	36	2.2 (1.7, 2.8)
Screening for gestational diabetes mellitus	32	37	1.2 (1.0, 1.5)
Screening for asymptomatic bacteriuria	42	43	1.0 (0.8, 1.3)
Screening for Rh-type	59	70	1.7 (1.3, 2.1)
Screening for tetanus immunization status	37	29	0.7 (0.5, 0.9)

[¥]derived from multivariable logistic regression analyses including all infrastructure-related and maternal sociodemographic variables: laboratory and ultrasound availability, maternal age at pregnancy registration, age at marriage, education and parity

ANC: Antenatal care; SFH: Symphysis-fundal height; CI: Confidence Intervals

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intervention that had a statistically significant lower odds ratio (adjusted OR = 0.7, 95% CI: 0.5, 0.9) (Table 5).

A higher proportion of multiparous women (≥four births) had their tetanus immunization checked, compared to nulliparous women (41% vs. 29%; adjusted OR = 2.1, 95% CI: 1.4, 3.2) (S1 Table). None of the other maternal sociodemographic variables had statistically significant associations with effective coverage (S1 Table).

Discussion

This is the first study to our knowledge to use effective coverage metrics for assessment of the Palestinian health system. By assessing the effective coverage of ANC interventions in public primary healthcare clinics, along with infrastructure-related and maternal sociodemographic factors that may be associated with effective coverage, it was possible to gain insight into ANC service provision in these clinics.

Studies informed by household survey data or direct observations have demonstrated lower effective coverage of ANC than crude service coverage in diverse settings such as Kenya [10], Ethiopia [37] and other countries in sub-Saharan Africa [22]. These studies have assessed the 'quality' component of effective coverage using a checklist of services provided during ANC, which would be conceptually equivalent to the outcome 'coverage of atleast one screening of ANC intervention' in our study. Almost all pregnant women in our sample had received a blood pressure measurement, and this result was similar to the findings from large multi-country studies of ANC content using survey data [7, 23].

In contrast to other studies of effective coverage that have reported a one-time provision of clinical interventions [10, 22], we also assessed the number and timing of screening tests for the full duration of the pregnancy to produce quality-corrected coverage of ANC interventions using facility-based data. According to outcome definitions used in this study, coverage of at least one screening is not dependant on follow-up care of pregnant women throughout the antenatal period. Coverage of appropriate number of screenings, on the other hand, reflects care provision throughout the antenatal period, but did not factor the timing of screening tests. Effective coverage of ANC interventions is essentially a combination of timely attendance rates and the provision of the prescribed screening test during attendance in the clinics.

Our ANC 4+ coverage rate (60%) was similar to that found in a study using facility-based data conducted in Jordan [38], which has a comparable population and health system as the

West Bank. Compared to ANC4+, attendance rates of ANC visits at guideline-specified timings was low in our sample of clinics. As a result, effective coverage of ANC interventions consisting of two-step (screening for gestational diabetes mellitus) or repeat screening tests (screening for anemia and hypertension, SFH measurement, and antenatal ultrasound) were significantly lower than both coverage of atleast one screening and coverage of appropriate number of screenings. A multi-country study reported that 10% of women in Jordan and 27% in Egypt had received a set of routine care components as part of ANC [23]. Despite methodological distinctions in the data source used, this study hints at a trend of low coverage of essential ANC interventions and can corroborate our findings. The difference between coverage of any screening test provided and effective coverage of screening for gestational diabetes (69% vs. 34%) was primarily due to the timing at which the tests were provided.

For ANC interventions consisting of a one-time screening test, the magnitude of the differences between coverage of at least one screening and effective coverage were smaller because timing of provision of ANC interventions played a less decisive role in achieving effective coverage. Indicators of hemoglobin and blood pressure measurement, which are commonly reported worldwide [39], had high coverage of at least one screening but much lower effective coverage in our study.

In general, two underlying contributing factors will lead to low effective coverage of ANC interventions, attendance and service provision. Hijazi et al [38] demonstrated that scheduling of follow-up ANC visits and counseling by care providers were strongly associated with women's utilization of ANC services in Jordan. Similar explorations are recommended to identify possible issues with providing timely appointments for follow-up ANC visits and potential barriers to ANC utilization in public clinics in the West Bank. Service provision is determined by adherence of care providers to prescribed ANC guidelines, which, in turn, could be influenced by training and supervision, or dissemination of guidelines. Other health systems factors such as lack of supplies of sufficient lab test kits have been shown to be determinants of service delivery in other contexts [19], but is less likely in our setting, considering the relatively high coverage of at least one screening of interventions that need such supplies.

Structural inputs to care such as infrastructure in health facilities have been shown to be weak predictors of content of ANC provided and clinical quality [40], although these results were for countries in sub-Saharan Africa with health systems that may be different from the West Bank. In our study, availability of laboratory and ultrasound in the clinics had varying degrees of associations with effective coverage of the different ANC interventions. A much lower proportion of women had SFH measured in clinics with an ultrasound compared to clinics without, presumably because of the use of antenatal ultrasound for fetal growth monitoring instead. It was beyond the scope of this paper to assess the quality of ultrasound-based fetal growth monitoring. Effective coverage of screening for hypertension and tetanus immunization status, that can be provided to pregnant women without a laboratory or ultrasound in the clinics were still associated with these infrastructure-related variables. Clinics with both a laboratory and ultrasound had a higher effective coverage of hypertension screening due to higher attendance rates in these clinics and relatively routine and non-invasive nature of taking blood pressure. The data available for this study could not shed light on the possible reasons for lower effective coverage of a simple screening test for tetanus immunization status in these better-equipped clinics.

In contrast to infrastructure-related factors, maternal sociodemographic characteristics (maternal age at pregnancy registration, age at marriage, education and parity) were not significantly associated with effective coverage. Differences in effective coverage based on sociodemographic variables may be due to characteristics that were not available for our study. For example, household income or expenditure are commonly used variables for equity analyses,

but were not available from the clinical records. Other studies done in LMIC have reported differences in the quality of ANC provided to clients based on their socioeconomic characteristics [16, 41]. These studies used data from household surveys and may have been able to capture populations across social, economic and demographic gradients, compared to our study using only facility-based data of women that receive ANC in public clinics.

In this study, we have presented one approach to the generation of effective coverage using facility-based data. For comprehensive health systems monitoring, such assessments capturing the timing and frequency of care may be used to complement the deficiencies of population-based survey data [23, 42]. Given the availability of routine health facility data from the newly implemented eRegistry in Palestine, health systems monitoring through such metrics is more feasible than with paper-based systems. Inferences derived from our analysis can provide policy-makers with information on some health system factors for consideration to increase effective coverage in public clinics. The eRegistry has incorporated several features designed to increase the level of effective coverage in this population. Specifically, interactive checklists with clinical decision support and automated dashboards providing performance feedback for care providers, can support the provision of complete ANC interventions, while tailored SMS messages to pregnant women, can encourage better uptake of ANC [29].

A limitation of this study was that only documented care was analyzed. Interventions may have been provided without documentation, but for many of these interventions, undocumented screening will be ineffective screening for the purpose of appropriate follow-up during pregnancy. Women may also have received additional targeted tests based on symptoms, as per care providers' clinical judgements, and subsequently not been re-screened at the time recommended by the guidelines. Such targeted tests may represent reasonable substitutes for routine screening, but would have been missed in our analyses. Effective coverage indicators of screening at specified timings will change over time, as the optimal number and timing of ANC contacts, as well as ANC content, continues to be a matter of debate and subject to evaluation [14, 43–45]. Similar to health systems in other countries in the region [23], pregnant women in the West Bank reportedly seek ANC from private providers and non-governmental organizations, sometimes in addition to receiving ANC from public health facilities. Therefore, the results of this study may not be indicative of the totality of effective coverage of ANC at the population-level in the West Bank, and cannot necessarily be used to estimate how changes in effective coverage in the public health system alone will impact maternal and neonatal health outcomes.

Conclusion

The choice and definitions of metrics can have substantial impact on health systems monitoring of ANC, both in terms of ascertaining the magnitude of the problem as well as identifying potential solutions. Effective coverage of ANC interventions in public primary healthcare clinics in the West Bank can be increased by improving the timely and complete provision of ANC interventions. Further exploration of specific aspects of care provision in primary healthcare clinics such as care providers' adherence to guidelines and women's perceptions and utilization of of ANC services in public clinics, can help address these issues to increase effective coverage of ANC interventions.

Supporting information

S1 Text. ANC interventions in the public health system not included in the analyses.
(DOCX)

S2 Text. Details of data used in the study.
(DOCX)

S1 Table. Effective coverage and maternal sociodemographic variables.
(DOCX)

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Additional file to paper II

Effective coverage and maternal sociodemographic variables

Table: Effective coverage (%) of essential ANC interventions across sub-groups based on maternal socioeconomic variables

	Effective coverage (%, 95% CI)							
Background variables	Screening for hypertension	SFH	Screening for anemia	Ultrasound	Screening for tetanus status	Screening for asymptomatic bacteriuria	Screening for Rh-type	Screening for gestational diabetes mellitus
Age (years)								
<=20	8	5	15	27	32	48	71	33
21-34	11	5	14	27	33	41	63	35
>=35	12	6	16	30	38	42	61	38
Education (years)								
<10	10	5	12	30	34	41	67	37
10-13	10	6	16	27	34	42	68	37
>13	11	5	13	27	32	43	60	32
Age at marriage (years)								
<20	11	5	14	27	33	44	67	35
>20	10	6	15	28	33	41	60	34
Parity								
0	10	6	15	27	29	44	67	33
1 – 4	10	5	14	26	35	41	62	36
≥4	13	6	12	33	41	44	62	35

CI: Confidence Intervals; SFH: Symphysis-fundal height; ANC: Antenatal Care

Table: Associations of effective coverage and maternal sociodemographic variables: adjusted odds ratios and 95% CI

	Adjusted OR (95% CI)[¥]							
Background variables	Screening for hypertension	SFH	Screening for anemia	Ultra-sound	Screening for tetanus status	Screening for asymptomatic bacteriuria	Screening for Rh-type	Screening for gestational diabetes mellitus
Age (years)								
<=20	1	1	1	1	1	1	1	1
21-34	1.7 (0.9,3.3)	1.1 (0.5,2.4)	1.0 (0.6,1.6)	0.9 (0.6,1.4)	0.8 (0.5,1.1)	0.8 (0.6,1.1)	0.9 (0.6,1.3)	1.1 (0.8,1.6)
>=35	1.8 (0.7,4.5)	1.1 (0.4,3.7)	1.3 (0.6,2.8)	0.8 (0.4,1.5)	0.8 (0.4,1.4)	0.8 (0.5,1.4)	0.8 (0.4,1.4)	1.3 (0.7,2.3)
Education (years)								
<10	1	1	1	1	1	1	1	1
10-13	0.9 (0.5,1.8)	1.2 (0.5,2.7)	1.3 (0.8,2.3)	0.9 (0.6,1.3)	1.2 (0.8,1.8)	1.0 (0.7,1.5)	0.9 (0.6,1.3)	1.0 (0.7,1.5)
>13	1.1 (0.6,2.2)	0.9 (0.4,2.2)	0.9 (0.5,1.7)	0.8 (0.5,1.2)	1.1 (0.7,1.7)	1.3 (0.8,1.7)	0.7 (0.4,1.0)	0.8 (0.5,1.2)
Age at marriage (years)								
<20	1	1	1	1	1	1	1	1
>20	0.7 (0.5,1.1)	1.2 (0.7,2.2)	1.2 (0.8,1.7)	1.2 (0.9,1.7)	1.2 (0.9,1.7)	0.9 (0.7,1.2)	0.8 (0.6,1.1)	1.0 (0.8,1.4)
Parity								
0	1	1	1	1	1	1	1	1
1 – 4	0.8 (0.5,1.2)	0.7 (0.4,1.3)	1.0 (0.7,1.4)	1.1 (0.8,1.4)	1.4 (1.0,2.0)	0.9 (0.7,1.2)	0.8 (0.6,1.0)	1.1 (0.8,1.4)
≥4	1.0 (0.5,2.0)	0.9 (0.4,2.2)	0.7 (0.4,1.4)	1.4 (0.9,2.2)	2.1 (1.4,3.2)	1.1 (0.7,1.6)	0.7 (0.5,1.1)	0.9 (0.6,1.4)

[¥]derived from multivariable logistic regression analyses including all infrastructure-related and maternal sociodemographic variables: laboratory and ultrasound availability, maternal age at pregnancy registration, age at marriage, education and parity; CI: confidence intervals; SFH: symphysis-fundus height

Paper 3

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Antenatal care data sources and their policy and planning implications: a Palestinian example using the Lives Saved Tool

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Abstract

Background: Policy making in healthcare requires reliable and local data. Different sources of coverage data for health interventions can be utilized to populate the Lives Saved Tool (LiST), a commonly used policy-planning tool for women and children's health. We have evaluated four existing sources of antenatal care data in Palestine to discuss the implications of their use in LiST.

Methods: We identified all intervention coverage and health status indicators around the antenatal period that could be used to populate LiST. These indicators were calculated from 1) routine reported data, 2) a Multiple Indicator Cluster Survey (MICS), 3) paper-based antenatal records and 4) the eRegistry (an electronic health information system) for public clinics in the West Bank, Palestine for the most recent year available. We scaled coverage of each indicator to 90%, in public clinics only, and compared this to a no-change scenario for a seven-year period.

Results: Eight intervention coverage and health status indicators needed to populate the antenatal section of LiST could be calculated from both paper-based antenatal records and the eRegistry. Only two could be calculated from routine reports and three from a national survey. Maternal lives saved over seven years ranged from 5 to 39, with percent reduction in the maternal mortality ratio (MMR) ranging from 1 to 6%. Pre-eclampsia management accounted for 25 to 100% of these lives saved.

Conclusions: The choice of data source for antenatal indicators will affect policy-based decisions when used to populate LiST. Although all data sources have their purpose, clinical data collected directly in an electronic registry during antenatal contacts may provide the most reliable and complete data to populate currently unavailable but needed indicators around specific antenatal care interventions.

Keywords: Lives Saved Tool (LiST), Antenatal care indicators, Priority setting in maternal and child health, Data for policy-making

Background

Setting effective and appropriate national, sub-national or sector-wide policies is a complex endeavor for health systems everywhere. Investigations of priority setting at national levels have demonstrated a high degree of similarity; critically, a unified understanding of the importance of the health problem is vital [1, 2]. A common complaint among policy makers is the inability to trust the evidence and data, especially when international and local numbers differ [3]. As a result, consistent sources of high quality and trustworthy data, tailored to the local context to inform planning processes, have proven to be a clear gap [4].

High quality data can be used at different points in the policy planning cycle, including for informing discussions as well as projecting the impacts of potential decisions, both of which are commonplace activities. The Lives Saved Tool (LiST) is a policy planning tool which utilizes information on the current health status of a country to

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project the health (mortality) implications of implementing specific health interventions for women or children [5]. LiST has been used for over ten years for evaluation, advocacy and strategic planning [6], across a wide variety of settings [7, 8]. An unsurprising criticism of LiST is the quality of data available to populate it [9] – in many instances, significant assumptions and estimations are required given the lack of primary data [10]. For any modelling tool, as for any policy setting process, high quality data is required to ensure that the results are accurate enough for usability [9].

LiST requires health status indicators (such as mortality and morbidity), effectiveness data (impact of interventions on health status), and coverage indicators (levels of utilization of health interventions). The coverage indicators required to populate LiST come from a variety of sources, including national statistics, household surveys, facility surveys and research studies, and are less amenable to global evaluation and summarizing due to variability in the implementation of many of these interventions. Few countries have routine high quality data on effective coverage (proportion of those getting an intervention among those in need) for assessing all aspects of their health system within the LiST structure. The frequency and quality of routinely reported data from health systems vary by topic and country, leaving alternative sources of data necessary. Many countries rely on externally funded, population-based surveys such as UNICEF's Multiple Indicator Cluster Survey (MICS) [11] and the Demographic and Health Surveys (DHS) [12] to collect service related data by asking women to remember the care received during their most recent pregnancy [13], often up to 2–5 years in the past.

The ever-expanding arena of information technology and digital registries has the potential to improve data availability around interventions delivered during antenatal care, childbirth and the postpartum period [13]. 'eRegistries' are electronic registries used at the point of care for recording health services delivered [14]. They are specifically designed to facilitate implementation of several digital health interventions such as: decision support tools, and audit and feedback (to aid health care workers in providing quality care); tailored behavior change communication text messages (to encourage women to attend care); and reporting (to provide aggregate data for health system managers and policy makers). An eRegistry for antenatal, postpartum and newborn care has been rolled out in primary health care clinics in the public sector in Palestine as part of a national implementation [15].

The validity of LiST outputs and results is closely linked to the kind of data that is input [5]. However, few studies have assessed the nature and magnitude of consequences to LiST results when using different sources of data. Users of LiST should be aware of such consequences to make informed decisions about intervention effectiveness when considering scale-up. Our objective was to model the scale up of antenatal care interventions in LiST, using all available data sources in Palestine – routine data, survey results, extracted medical records and the eRegistry, to explore how the results might vary, and the implications of using these varied sources to make decisions.

Methods

Study design

This secondary data analysis utilized multiple sources of health information for modeling mortality and morbidity impacts of scaling up coverage of routine health interventions delivered during the antenatal period in the Lives Saved Tool.

Indicators for the Lives Saved Tool

We identified all coverage and health status indicators needed to fully model antenatal care in the Lives Saved Tool (LiST). For each of those indicators, we then selected those that were: 1) relevant to the population in the West Bank and 2) available in any of the known data sources. Malaria, HIV/AIDS and syphilis indicators were not considered as these are not common health issues in the Palestinian population. Neither calcium supplementation nor balanced energy supplementation were part of the national guidelines recommended for the public health system in the West Bank, and were not considered. Although mortality data were also needed, they were not extracted from any of the data sources; identical default mortality data from the World Health Organization and LiST were used for all analyses.

Data sources

Routine reporting data

Routine data for 2016, as reported by clinical workers, were available for the West Bank, including number of women attending antenatal care at public vs. other centers [16].

Population based survey data

The most recent population-based survey in Palestine which included antenatal care data was the 2014 Multiple Indicator Cluster Survey, published in 2015 [17]. As part of this population-weighted survey, a nationally representative sample of women were asked about utilization of antenatal care, including the location and type of tests performed for pregnancies completed within the past 2 years. Using the published weights, we calculated the proportion of women attending antenatal care at public facilities. All data from live births in the West Bank were included in this analysis; no available records were excluded for any reason.

Data from antenatal records

Paper-based records In preparation for the national implementation of the eRegistry in Palestine, all antenatal records from 17 primary healthcare clinics in five districts in the West Bank were extracted for the year 2015, for a total of 1369 pregnancies [18]. The clinics were randomly selected to be representative of the districts where the first phase of the national implementation would take place. There were no individual inclusion or exclusion criteria; records from all pregnant women were extracted. Clinical data were extracted from the paper-based records and entered into electronic data entry forms that were identical to the data entry forms of the eRegistry (see below). Quality checks of data entry were carried out; 10% of all paper-based records were entered twice by the data extractors.

eRegistry data Care providers at public antenatal clinics in 76 facilities in five districts in the West Bank directly entered antenatal care records into an eRegistry throughout the year 2017. These clinics include all the primary health care clinics in the same five districts as the paper-based record extraction. There were no individual inclusion or exclusion criteria; records from all pregnancies entered into the eRegistry were included in the analysis. Records with no valid data entered were excluded. We used this data for all pregnant women registered on or after January 1, 2017 and passed 44 weeks of gestation as of 30th of April 2018.

Differences between the paper and eRegistry records Although the paper extraction and the eRegistry were designed to be identical, differences did exist; specifically, they contained notably different data on iron-folate supplementation (Table 1). In the paper records, a single data point recorded whether iron-folate supplements were given. In the eRegistry, integrated clinical decision support reminded the care provider of the specific dose of iron-folate required, and care providers documented whether or not the suggested management was performed.

Calculation of LiST indicators from paper-based and eRegistry antenatal record data For LiST analyses, management indicators require data on 1) the proportion of women eligible for screening (including seeking care) who were screened correctly and at the correct time, and 2) the proportion of those identified who were correctly managed, among those that had a positive screening test (Fig. 1). This reflects the proportion of women who truly had a condition and were correctly managed of those that attended care at public facilities (Fig. 1).

In the West Bank, diabetes screening consists of urine sugar testing of all pregnant women at the booking antenatal visit, a blood sugar test at 24–28 gestational weeks for those not already positive, and a glucose challenge test based on blood sugar test results (Fig. 1). For women with a result greater than 140 mg/dl on the glucose challenge test, correct management is referral. Hypertension screening requires serial blood pressure measurement at all antenatal care visits. For mild hypertension, recommended management includes urine protein testing. Screening for pre-eclampsia requires a urine protein test following measurement of hypertension after 20 weeks gestation. Referral is the recommended management for women with chronic hypertension, moderate or severe gestational hypertension, hypertension with proteinuria or symptoms of preeclampsia. We assumed correct management for all correct referrals regardless of whether women sought that additional care at the referral facility or not. We also assumed equitable screening and management of all pregnant women irrespective of health or socio-economic characteristics. Figure 2 contains a worked example of how the indicator for diabetes management was calculated, based on the construction in Fig. 1. Additional File 2 displays the detailed calculations. All data are available upon request.

For indicators unable to be calculated directly from the data sources, we utilized the Kanyangarara method [19], developed specifically to utilize distal determinants to predict coverage for LiST.

Lives Saved Tool analyses

LiST (version 5.71; Avenir Health) predicts the number of deaths and anemia cases that would have occurred under a given population and health scenario, combined with coverage of health interventions and how they change over time [20]. We compared two national level scenarios: 1) a steady state scenario from 2017 to 2025 and 2) a scenario where coverage of antenatal care interventions increased to 90% from baseline in public facilities only (with no change in other facilities) in 2018, and then remained at a steady state through 2025. The primary result is the difference in the number of deaths and anemia cases during 2018–2025 between the two scenarios. All sources reported data from slightly different time periods, and to mimic a typical situation, we applied the most recently available data to the year 2017. We assumed that the quality of care delivered to women attending both public and other facilities was constant.

The proportion of women attending antenatal care in public facilities for the MICS analysis came directly from the survey itself. For LiST analyses using the other three data sources, we used the routinely reported estimates of the proportion of women attending public facilities. Over time, we assumed no change in the proportion of women attending public vs. other clinics nor in the quality of care provided at other clinics.

Table 1 Definition and calculation of antenatal care indicators for the Lives Saved Tool

	LiST Indicators	Reporting	Household Survey	Antenatal Records	
		Routine (2016)	MICS (2014)	Paper (2016)	eRegistry (2017)
Coverage	% of women with diabetes with appropriate management	Cases of diabetes referred / (pregnant women registered X diabetes incidence‡)	Indirect calculation; Kanyangarara method†	% of women screened for diabetes at the correct time in pregnancy, and referred if needed; see Fig. 1	
	% of women with hypertensive disorders in pregnancy with appropriate management	NA	Indirect calculation; Kanyangarara method†	% of women screened for hypertension at the correct time in pregnancy, and referred to the high-risk clinic if needed	
	% of women with appropriate tetanus toxoid vaccination	NA	NA	% of women who are vaccinated according to guidelines	% of women who are vaccinated according to guidelines at enrollments AND given a booster if unknown/ unimmunized
	% of women with pre-eclampsia who have been referred	Cases of pre-eclampsia referred / (pregnant women registered X pre-eclampsia incidence‡)	Indirect calculation; Kanyangarara method†	% of pregnant women screened for pre-eclampsia at the correct time in pregnancy and referred to the hospital, if needed	
	% of pregnant women with iron and folic acid supplements	NA	NA	% of women given iron and folic acid supplements	% of non-anemic women given routine iron supplements and % of anemic women treated
Health status	% of pregnant women with anemia	NA	NA	% of pregnant women with a hemoglobin value of < 11 g/dl or less at any point during the pregnancy	
	% of women with low body mass index	NA	NA	% of women with body mass index < 18.5 at a booking visit	% of women with body mass index < 18.5 at a booking visit
	% of women with severe anemia	NA	NA	% of women with a hemoglobin level of < 7 g/dl or less ever	

NA Not available; †Additional File 1 for details. ‡Diabetes and pre-eclampsia incidence calculated from paper-based antenatal records

Diabetes guidelines

Appropriate screening and management of diabetes during pregnancy include two stages of screening at two different pre-defined time points during the pregnancy as presented below.

- **ANC visit before 20 weeks gestational age**
  - *Urine sugar test*
    - Normal result → standard follow-up at the 24-28 week visit
    - Abnormal results → random blood sugar test
      - Normal blood sugar test result requires standard follow-up at the 24-28 week visit
      - Abnormal blood sugar test result requires referral*
- **ANC visit 24-28 weeks gestational age**
  - *Blood sugar test*
    - Normal result → no action
    - Intermediate result → glucose challenge test
      - No action for normal glucose challenge test result
      - Abnormal glucose challenge test result requires referral*
    - Abnormal blood sugar test result requires referral

LiST Indicator formulation

The LiST indicator was operationalized as the percent of women with correct screening practices multiplied by the percent of women with correct management practices (formula 1). Screening is assumed to refer to the proportion of women who are correctly identified as having diabetes (formula 2). Management is the proportion of women who are identified with diabetes who are correctly referred to additional care (formula 2).

Formula 1

$$\%\ Correct\ Screening \times \%\ Correct\ Management$$

Formula 2

$$\left(\frac{Cases\ identified}{Cases\ in\ sample}\right) \times \left(\frac{Cases\ referred}{Cases\ identified}\right)$$

The cases identified and the cases referred (among those identified) can be calculated separately for each of the time periods and for each of the potential stages. The projected number of cases that would be expected in this population (assuming no differential selection in either screening or management) can be calculated based upon proportions who have been screened at all stages as shown below. Formula 3a shows the needs when two screening test results are required (i.e. ANC <20 weeks) while formula 3b shows the needs when multiple screening options/results are possible (i.e. ANC 24-28 weeks):

Formula 3

$$a)\ \left(\frac{\#\ abnormal\ results\ on\ screening\ 2}{\%\ screen\ 1\ \times \%\ screen\ 2\ \times \%\ timely\ 1st\ ANC}\right)$$

$$b)\ \left(\frac{\#\ abnormal\ results\ on\ screening\ 1}{\%\ screen\ 1\ \times \%\ timely\ 2nd\ ANC}\right) + \left(\frac{\#\ abnormal\ results\ on\ screening\ 2}{\%\ screen\ 1\ \times \%\ timely\ 2nd\ ANC \times \%\ screen\ 2}\right)$$

**in primary care clinics, referral is to a high-risk clinic. If condition is first identified when the woman is already at the high-risk clinic, referral is considered done.*

ANC: Antenatal Care

Fig. 1 Conversion of diabetes guidelines in Palestine into an indicator for the Lives Saved Tool (LiST)

Results

Data to indicators

The coverage and health status indicators available for input in LiST are presented in Table 1 along with the exact definitions and calculations for each data source. The number of women managed with diabetes or pre-eclampsia were available from the routine data, although incidence values were not available. To allow this analysis to proceed, we required a source of incidence, which we derived from our medical record (paper-based) review. Indicators of management of diabetes, hypertensive disorders and pre-eclampsia were not available from the MICS. They were indirectly calculated using the Kanyangarara method [19] (Additional File 1). Although available in some MICS, the Palestinian survey did not include indicators related to tetanus vaccination or iron supplementation. Although data on symphysis-fundal height measurement were available in both the paper-based records and eRegistry data, management data were not; identification and management of fetal growth restriction was not calculated for any source. Data from paper-based records and the eRegistry included all pregnancy indicators of interest. Women with moderate or severe hypertension or potential pre-eclampsia are referred to hospitals and do not return to the primary care clinics for ANC management; as a result, the proportion of women correctly identified and managed with pre-eclampsia may be incomplete. In addition, the amount of missing data for tetanus toxoid vaccination was notably different with 42% missing in

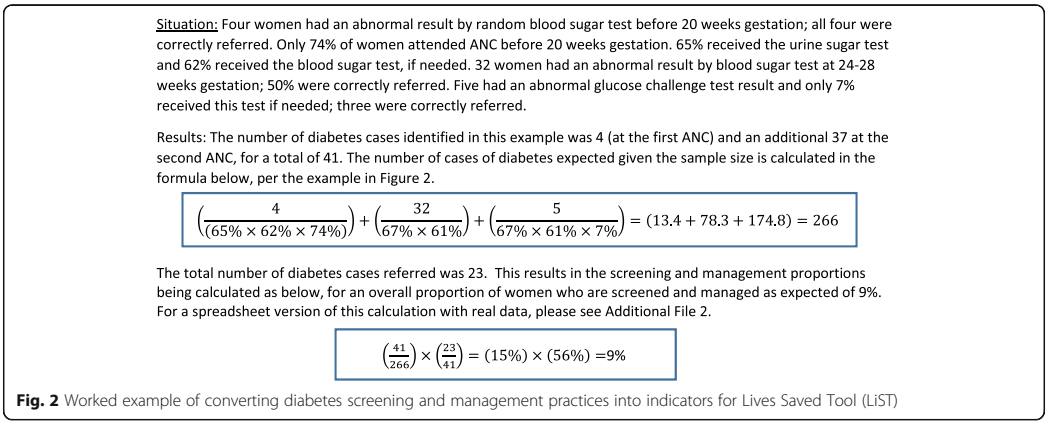

Fig. 2 Worked example of converting diabetes screening and management practices into indicators for Lives Saved Tool (LiST)

paper records and only 7% missing in the eRegistry, although missing data proportions were much more similar in the two data sources for other indicators.

Five coverage indicators and three health status indicators for the West Bank could be calculated from the four sources of antenatal care data (Table 2). The routinely reported data populated two coverage indicators and none of the health status indicators, while the MICS data could directly populate none of the coverage or health status indicators. The MICS data could be used to indirectly calculate three of the coverage indicators. Data from paper-based antenatal records and the eRegistry were used to calculate all five of the coverage indicators and all three of the health status indicators.

LiST analysis

Table 3 summarizes the baseline and target inputs to a national level LiST analysis with coverage of appropriate care in public West Bank clinics increased to 90%, assuming no change in the proportion of women attending public facilities and no change in quality of care provided at other facilities. When we used routinely reported data or MICS data as the source for LiST analyses, increasing coverage would lead to no newborn deaths or anemia cases being averted (Table 4). Using routinely reported data, the LiST analysis estimated that 16 maternal deaths and 239 stillbirths would be averted. Using MICS data, LiST suggested that far fewer maternal deaths and stillbirths would be averted (Table 4). In contrast, the LiST analysis using individual level data from both the paper-based antenatal care records or the eRegistry led to comparable estimates of more maternal deaths potentially being averted, and that improving the quality of care in Palestine would also avert a number of newborn deaths. While LiST analyses based on routine data and MICS would be unable to identify a reduction in anemia cases by improving anemia prevention, both sources of individual level data suggested significant gains from better prevention.

The specific interventions resulting in these deaths being averted were similar across data sources, with tetanus toxoid preventing all newborn deaths and iron folate supplementation preventing all anemia morbidity. The lack of data on hypertension management in the routine data resulted in all deaths being averted by pre-eclampsia management, while only 25% were prevented by pre-eclampsia management using the MICS data. Both data from paper-based records and the eRegistry suggested a similar proportion of maternal deaths being averted by pre-eclampsia management and hypertensive disorders management. Stillbirths were predominantly averted by pre-eclampsia management with a varying proportion averted due to diabetes management, based on the source utilized (Table 4).

Table 2 Summary of indicator availability by source

		Routine Data	MICS	Paper records	eRegistry
Coverage	Directly	2/5	0/5	5/5	5/5
	Indirectly*	0/5	3/5	0/5	0/5
	All	2/5	3/5	5/5	5/5
Health status		0/3	0/3	3/3	3/3

*Using the Kanyangarara method [19]

Discussion

Data for decision-making is a common cry in public arenas. However, not all data are the same, and the implications of using the various alternative data sources available can be significant, especially when multiple choices exist, such as in the case of Palestine. Selection of data source can be even more critical when used as inputs into a formal analytic framework, as many policy

Table 3 National level Indicators from all sources used as inputs in the LiST analysis

		Reporting	Survey	Antenatal Records	
Analysis	Indicators	Routine (2016)	MICS (2014)	Paper (2016)	eRegistry (2017)
National baseline (applied to 2017)	% of all pregnant women who have completed the appropriate tetanus toxoid vaccination schedule	NA	NA	85.4	92.1
	% of pregnant women taking the appropriate iron or folate supplementation	NA	NA	90.3	64.4
	% of women with hypertensive disorders in pregnancy who are correctly managed	NA	68.9†	15‡	35‡
	% of women with diabetes with appropriate case management	71.9	35.1†	7‡	10‡
	% of women with pre-eclampsia during pregnancy who are correctly managed	51.7	72.9†	11‡	14‡
	Anemia	27*	27*	37.3	37.7
	Severe anemia	0.272*	0.272*	0	0.1
	BMI	3.1*	3.1*	2.8	4.4
National target assuming 90% coverage in public sector (applied to 2018–2025)	% of all pregnant women who have completed the appropriate tetanus toxoid vaccination schedule	NA	NA	92,0	95,7
	% of pregnant women taking the appropriate iron or folate supplementation	NA	NA	94.7	80.6
	% of women with hypertensive disorders in pregnancy who are correctly managed	NA	75.5†	53.6	64.5
	% of women with diabetes with appropriate case management	84.7	47.3†	49.2	50.9
	% of women with pre-eclampsia during pregnancy who are correctly managed	73.6	74.5†	51.4	50.9
	Anemia	27.2*	27.2*	37.3	37.7
	Severe anemia	0.272*	0.272*	0	0.1
	Body mass index (BMI)	3.1*	3.1*	2.8	4.4

*LiST defaults: Finucane 2011 [28], Stevens 2013 [29]; †Using the Kanyangarara method [19] ‡See Additional File 2 for details

makers do not see the raw data but only the results of the processing, assumptions, estimates, and analysis. Global agencies and research teams publish consensus estimates of mortality with uncertainty bounds, but estimates of health intervention coverage show more variability and are less widely available in general. The availability of new sources of local and timely data and indicators is likely to increase as countries shift towards digital data and case-based collection methods. The evaluation of these new data sources is critical to assess their potential for improving the care being delivered and to appropriately inform planning processes.

In this analysis, the four data sources yielded notably different results when utilized in LiST. The maternal deaths averted ranged from 5 to 39, or a reduction of maternal mortality from 1 to 6%. At the same time, the composition of interventions to save these lives varied from 100% for pre-eclampsia management to 75% for hypertensive disorders management. These differences would likely result in different policy and practice decisions being taken. Similar, but less dramatic differences could be seen in newborn, stillbirth, and anemia results using the different data sources. Although the absolute differences were relatively small in this particular context, they would be magnified greatly in countries and settings with higher mortality and morbidity rates, or if interventions beyond antenatal care were included.

The power of the Lives Saved Tool can be maximized when data of better quality and quantity are available to populate it. However, in most country settings, several data points are not directly available in either routine reports or household surveys. Drawing data directly from clinical records allows for a more complete and complex picture of antenatal care and covers almost all data needs. Many surveys, such as the MICS, only include data from live-births [17], thus excluding data on women who experienced stillbirths or miscarriages and their potentially complicated pregnancies. Another aspect of clinical data, not present in most survey or routine data sources, is the longitudinal perspective within a pregnancy. Longitudinal analyses across periods of time and healthcare contacts allow the ability to include only

Table 4 Morbidity and mortality results

		Routine Data	MICS	Paper records	eRegistry
Morbidity & mortality	Maternal lives saved	16	5	35	39
	Newborn lives saved	0	0	49	39
	Stillbirths averted	239	45	285	270
	Maternal anemia cases averted	0	0	16,444	42,064
Interventions averting mortality and morbidity	Maternal	Pre-eclampsia management (100%)	Hypertensive disease management (75%); Pre-eclampsia management (25%)	Hypertensive disease management (41%); Pre-eclampsia management (59%)	Hypertensive disease management (45%); Pre-eclampsia management (55%)
	Newborn	–	–	Tetanus toxoid (100%)	Tetanus toxoid (100%)
	Stillbirth	Pre-eclampsia management (84%); diabetes management (16%)	Pre-eclampsia management (52%); diabetes management (48%)	Pre-eclampsia management (83%); diabetes management (17%)	Pre-eclampsia management (82%); diabetes management (18%)
	Anemia	–	–	Iron Folate (100%)	Iron Folate (100%)
Rates, ratios, percentages	Maternal Mortality Ratio (2017/2025) % change	46/44 3%	46/45 1%	46/43 6%	46/43 6%
	Neonatal Mortality Rate (2017/2025) % change	11/11 0%	11/11 0%	11/11 < 1%	11/11 < 1%
	Stillbirth Rate (2017/2025) % change	7/7 2%	7/7 < 1%	7/7 3%	7/7 3%
	Pregnant women with anemia (%) (2017/2025) % change	27/27 0%	27/27 0%	37/36 3%	38/35 8%

managements based upon true conditions, ensuring that only appropriate and correct referrals are included in the calculation rather than all referrals. An ideal data source for complex indicators would be longitudinally collected at the point-of-care to minimize the need for post data-collection processing. This would ensure that both numerators and denominators were collected simultaneously, and mitigate issues from recall bias of either care providers or mothers. In addition, one of the largest criticisms of the Lives Saved Tool is the quality of estimates around maternal mortality. The current use of indirect estimates greatly increases the likely uncertainty around the LiST estimates of maternal mortality. These results should increase the validity and reliability of future analysis with such data, simply because fewer assumptions will be needed.

The paper-based routine health information systems in Palestine, as in many other places, rely on care providers identifying key characteristics about patients and reporting to district and national health authorities, who aggregate and process the data to generate national indicators. The validity of any individual diagnosis is unknown. This additional reporting burden on care providers limits the ability to demand reporting of a comprehensive set of clinical data, and thus results in a reporting system focused on only the highest priority indicators. Complex health conditions and reporting chains can lead to either over- or under-reporting. For example, knowing the number of women referred for diabetes is useful, but does not indicate the proportion of women correctly diagnosed with diabetes or appropriately referred, leaving the system unable to rectify underlying problems. To create more actionable indicators, providers would need to document every diabetes test, the number of women positive and the number referred according to recommended guidelines. This extensive task is not likely to be a valuable use of time in a paper-based system. The routine system in Palestine also relies on reporting by two different levels of clinics (primary and referral), which makes it difficult to ensure that women are correctly included only once, in either the numerator or denominator, potentially leading to biases. Routine reporting data should be limited and focused on critical indicators that cannot be collected easily in clinical data sources or those needed to triangulate with other sources.

Typically, the primary source of coverage data used in LiST is household survey data, such as the MICS presented here. However, very little data are available from these surveys to directly populate antenatal care (or childbirth care) indicators. Information on antenatal services received or antenatal care attendance can be used to indirectly calculate several other indicators. However, these estimates are dependent on maternal recall, which may be biased towards experiences of women with difficult pregnancies who would tend to remember care more completely relative to uneventful pregnancies and deliveries, while excluding pregnancies ending in stillbirth or miscarriage. Although these indirect indicators (together with non-antenatal care indicators) can be useful for planning, these surveys are typically conducted only every five years making their input less timely for shorter-term planning or course-correction. Additional questions should be asked about the utility of these indirect estimates (which were formulated with sub-Saharan African data) when compared to actual values extracted from antenatal care records. If the Kanyangarara formula is applied to the paper-based antenatal records and the eRegistry, respectively, approximately 62 and 61% of women are estimated to be correctly managed for hypertension while the clinical data indicated that only 7 and 10% were correctly managed. The differences were much smaller for the diabetes management indicator which were predicted to be 29 and 31% respectively, while the actual clinical values were 13 and 35%, respectively.

Data extracted from paper-based antenatal care records and the eRegistry contained the greatest quantity of data for direct analysis. They also allowed for computing indicators that most closely matched the ideals of the Lives Saved Tool (Table 3). Although differences in documentation may account for the different values reported, it should also be noted that indicators from the eRegistry document more carefully the details around management, which are not typically recorded in the paper records, and thus should theoretically be a more precise indicator of correct management. The simplified single checkbox of any iron-folate supplementation in paper records may have over-estimated current performance as the LiST analysis estimated more than two-fold higher numbers of anemia cases being averted in the eRegistry-based analysis compared with paper records. Assuming that care providers are correctly completing their documentation, these results should be more valid and more reliable than survey based data or routine reporting with the multiple additional layers of data processing required. They are certainly more direct estimates that have the potential to be more representative of facility care since they also include all pregnancies, not just all live-births.

Extracting data from paper-based records on a regular basis is neither feasible nor sustainable for routine monitoring due to the expense and tardiness of such a system, and without the quality assurance routines used in this study, also by the likelihood of transcription errors. In addition, paper records can be incomplete and do not have built-in validations at data entry, as seen with the tetanus toxoid vaccination data.

Although the development of an eRegistry is time-consuming and resource-intensive, and up-front implementation costs are relatively high, the benefits can be wide-ranging by integrating multiple digital health interventions in a single system. In Palestine, the point-of-care data entry currently serves as an interactive checklist with clinical decision support, with integrated audit and feedback components and a reminder system for pregnant women. On the back-end, the system routinely generates key indicators at national, sub-national and clinic levels without requiring burdensome reporting.

A limitation of the eRegistry system in Palestine is that it is currently only available in public sector facilities and does not include private or non-governmental organization (NGO) facilities, nor public hospitals. Population coverage cannot be measured with the eRegistry data in this setting. Although the lack of data from private and NGO facilities does not affect the analysis of care delivered at public facilities, LiST analysis might predict larger health improvements than actually could occur, due to missing data on referred patients who seek care in external facilities. At the same time, population based surveys can provide the data needed to understand the flow of patients between public and private or NGO sectors and thus act as a calibration of the clinical data, in conjunction with routine reported data. The lack of data from any of the hospitals also limited the ability to define the interventions in terms of full quality of care at referral centers. However, it is likely that adding this information would only decrease the proportion of women correctly managed.

Conclusions

This study has clearly demonstrated the notable variability of information available for decision making based on the data source chosen in Palestine. Selection of the most complete and appropriate data source for policy and planning is critical. Many frameworks have been developed that attempt to characterize the features of priority setting and networks for informing policy decisions [21–24]. Studies have evaluated the barriers and facilitators to evidence-based decision making at national and local levels, and systematic reviews have described systems for incorporating research evidence into decision-making

and less frequently, described the utilization of burden of disease data in decision-making [25, 26]. This paper feeds the discussion around how to support evidence informed decision-making at national levels by outlining the pros and cons of various data sources. We demonstrated the significant data driven benefits for the health system from utilizing data automatically extracted from a digital registry of health contacts – both in terms of quantity and quality. These distal benefits of an eRegistry along with more immediate clinical benefits to care providers and clients can also be used to inform a cost-benefit analysis for implementing complex health system interventions.

Additional files

Additional file 1: Calculations for calculating coverage with the Kanyangarara method This file contains the raw data used and resultant coverage data generated when using the Kanyangarara method. (XLSX 9 kb)

Additional file 2: Detailed calculations of coverage indicators from paper records and from the eRegistry. This file contains the detailed and stepwise calculations of the hypertension, pre-eclampsia and diabetes coverage indicators calculated from both the paper records and the eRegistry. (XLSX 52 kb)

Abbreviations
ANC: Antenatal care; DHS: Demographic and Health Survey; LiST: Lives Saved Tool; MICS: Multiple indicator cluster survey; MMR: Maternal mortality ratio; NGO: Non-governmental organization

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Ethical approvals and consent to participate
Ethical approvals for access to anonymous data from paper-based records were obtained from the Palestinian Health Research Council (PHRC/HC/272/17) and the Regional Committee for Medical and Health Research Ethics, Norway (2017/1537–3). Approval for access to anonymized data from the eRegistry for the data and indicators required for the study analyses was obtained from the Palestinian Ministry of Health, in accordance with the legal framework for eRegistry data use [27].

Author contributions
IKF defined the objectives of the study, undertook the Lives Saved Tool (LiST) analyses and wrote the first draft of the manuscript. MV identified the data sources and indicators, coordinated the data collection from paper records and helped writing the manuscript. BG is the project leader of the eRegistry implementation in Palestine, and facilitated access to the different data sources. JFF contributed to refining the objectives of the study, defining the indicators and outcomes and writing the manuscript. All authors have read and approved this version of the manuscript.

Availability of data and materials
The MICS and routine Palestinian data are publically available as referenced. The paper-based medical record data and the eRegistry data belong to the Palestinian Ministry of Health, and are available upon request to them with appropriate ethical approval.

Consent for publication
Not applicable.

Competing interests
The authors declare that do not have any competing interests.

Publisher's Note

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Additional file to paper 3

Calculations for deriving coverage with the Kanyangarara method

		Intercept	ANC4+	Blood sample	Urine	ANC4+	Blood sample	Urine sample	Formula result
MICS 2014		Regression Estimates				MICS 2014 Values			
Diabetes	Proportion of women with diabetes who are both diagnosed and treated if needed	-3,21		2,61		95,5	97,6	97	34,0
Hypertension	Proportion of women with pregnancy induced hypertension who are both diagnosed and treated if needed	-1,62			2,5	95,5	97,6	97	69,1
Pre-eclampsia	Proportion of women with pre-eclampsia who are both diagnosed and treated if needed	-6,44	2,56	4,91		95,5	97,6	97	68,9
Paper-based records		Regression Estimates				Paper-based record Values			
Diabetes	Proportion of women with diabetes who are both diagnosed and treated if needed	-3,21		2,61		61,3	89,5	85,2	29,4
Hypertension	Proportion of women with pregnancy induced hypertension who are both diagnosed and treated if needed	-1,62			2,5	61,3	89,5	85,2	62,5
Pre-eclampsia	Proportion of women with pre-eclampsia who are both diagnosed and treated if needed	-6,44	2,56	4,91		61,3	89,5	85,2	38,3
eRegistry		Regression Estimates				eRegistry Values			
Diabetes	Proportion of women with diabetes who are both diagnosed and treated if needed	-3,21		2,61		53,5	91,9	83	30,8
Hypertension	Proportion of women with pregnancy induced hypertension who are both diagnosed and treated if needed	-1,62			2,5	53,5	91,9	83	61,2
Pre-eclampsia	Proportion of women with pre-eclampsia who are both diagnosed and treated if needed	-6,44	2,56	4,91		53,5	91,9	83	36,4

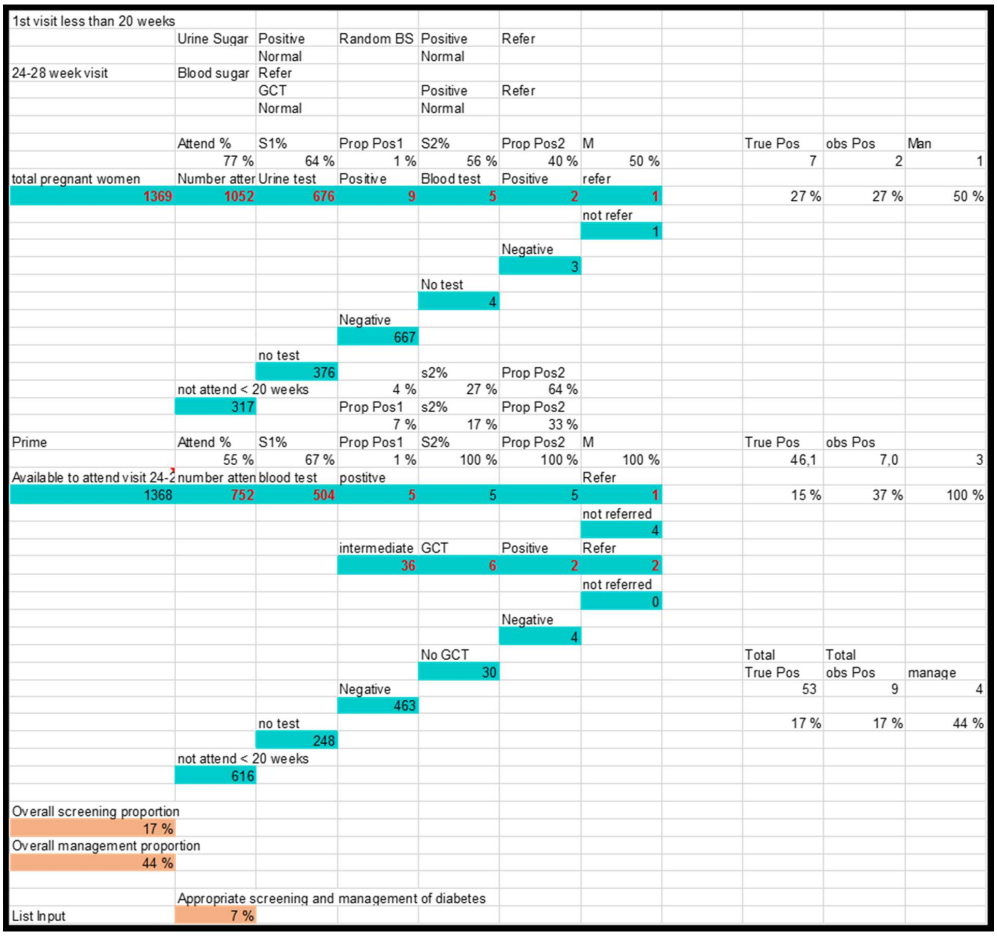
Additional file 2

Detailed calculations of indicators from paper records and from the eRegistry

Diabetes – eRegistry data

1st visit less than 20 weeks												
	Urine Sugar	Positive	Random BS	Positive	Refer							
		Normal		Normal								
24-28 week visit	Blood sugar	Refer										
		GCT		Positive	Refer							
		Normal		Normal								
								True Positive (N)	Observed Positive (N)	Managed		
	Timely Attendance %	S1%	Prop Pos1	S2%	Prop Pos2	M						
	74 %	65 %	1 %	62 %	31 %	100 %		13,4072	4	4		
total pregnant women	Number attend ANC <	Urine test	Positive	Blood test	Positive	refer						
4403	3250	2122	21	13	4	4		30 %	30 %	100 %		40 %
						not refer						
						0		13,40723555				
					Negative							
					9							
				No test								
				8								
			Negative									
			2101									
		no test										
		1128		s2%	Prop Pos2							
	not attend < 20 weeks		6 %	21 %	78 %							
	1153		Prop Pos1	s2%	Prop Pos2							
			11 %	7 %	29 %							
								True Positive (N)	Observed Positive (N)	Managed		
Prime	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M						
	67 %	61 %	2 %	100 %	100 %	75 %		213,2	36,0	19		
Available to attend visit												
24-28	number attend 24-28	blood test	postitve			Refer						
4399	2332	1786	32	32	32	16		17 %	8 %	75 %		46 %
						not referred						
						16						
			intermediate	GCT	Positive	Refer		78,8174692				
			191	14	4	3		134,4119341				
						not referred		213,2294033				
						1						
					Negative							
					10							
				No GCT								
				177								
			Negative									
			1563									
		no test										
		1146										
	not attend < 20 weeks											
	1467											
								True Positive (N)	Observed Positive (N)	Managed		
Overall screening proportion												
18 %								227	40	23		
Overall management proportion												
58 %								18 %	18 %	58 %		
	Appropriate screening and management of diabetes											
List Input	10 %											

Diabetes – paper-based clinical records data

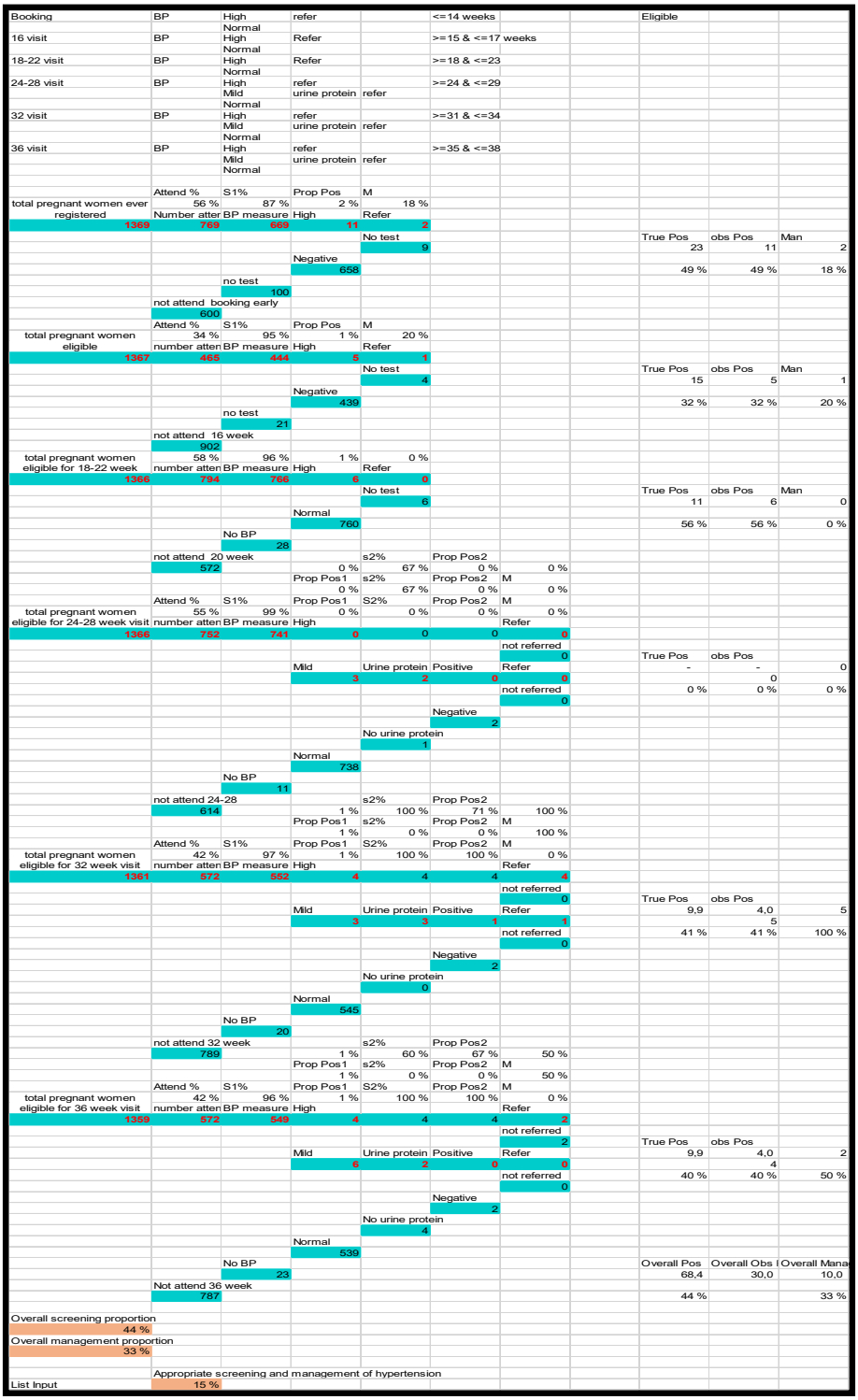


1st visit less than 20 weeks										
	Urine Sugar	Positive	Random BS	Positive	Refer					
		Normal		Normal						
24-28 week visit	Blood sugar	Refer								
		GCT		Positive	Refer					
		Normal		Normal						
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M		True Pos	obs Pos	Man
	77 %	64 %	1 %	56 %	40 %	50 %		7	2	1
total pregnant women	Number atter	Urine test	Positive	Blood test	Positive	refer				
1369	1052	676	9	5	2	1		27 %	27 %	50 %
						not refer				
						1				
					Negative					
					3					
				No test						
				4						
			Negative							
			667							
		no test								
		376		s2%	Prop Pos2					
	not attend < 20 weeks		4 %	27 %	64 %					
	317		Prop Pos1	s2%	Prop Pos2					
			7 %	17 %	33 %					
Prime	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M		True Pos	obs Pos	
	55 %	67 %	1 %	100 %	100 %	100 %		46,1	7,0	3
Available to attend visit 24-2	number atten	blood test	postitve			Refer				
1368	752	504	5	5	5	1		15 %	37 %	100 %
						not referred				
						4				
			intermediate	GCT	Positive	Refer				
			36	6	2	2				
						not referred				
						0				
					Negative					
					4					
				No GCT				Total	Total	
				30				True Pos	obs Pos	manage
			Negative					53	9	4
			463							
		no test						17 %	17 %	44 %
		248								
	not attend < 20 weeks									
	616									
Overall screening proportion										
17 %										
Overall management proportion										
44 %										
	Appropriate screening and management of diabetes									
List Input	7 %									

Hypertension – eRegistry data

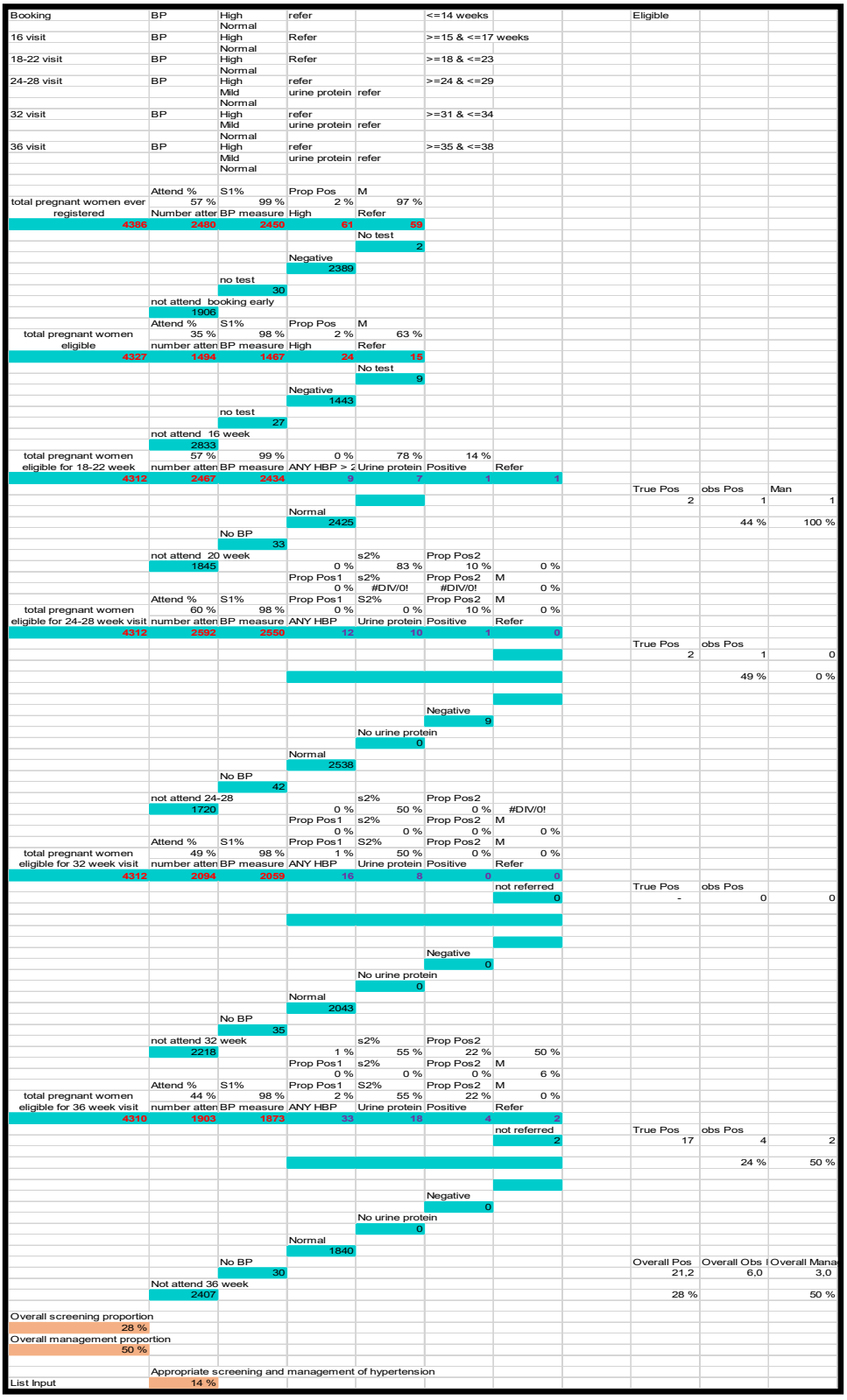
Booking	BP	High	refer		<=14 weeks			Eligible		
		Normal								
16 visit	BP	High	Refer		>=15 & <=17 weeks					
		Normal								
18-22 visit	BP	High	Refer		>=18 & <=23					
		Normal								
24-28 visit	BP	High	refer		>=24 & <=29					
		Mild	urine protein	refer						
		Normal								
32 visit	BP	High	refer		>=31 & <=34					
		Mild	urine protein	refer						
		Normal								
36 visit	BP	High	refer		>=35 & <=38					
		Mild	urine protein	refer						
		Normal								
	Attend %	S1%	Prop Pos	M						
total pregnant women ever registered	57 %	99 %	2,5 %	97 %	96 %					
	Number atter	BP measure	High	Refer						
4386	2480	2450	61	59						
				No test				True Pos	obs Pos	Man
				2				109	61	59
			Negative							
			2389					56 %	56 %	97 %
		no test								
		30								
	not attend booking early									
	1906									
	Attend %	S1%	Prop Pos	M						
total pregnant women eligible	35 %	98 %	2 %	63 %	61 %					
	number atter	BP measure	High	Refer						
4327	1494	1467	24	15						
				No test				True Pos	obs Pos	Man
				9				71	24	15
			Negative							
			1443					34 %	34 %	63 %
		no test								
		27								
	not attend 16 week									
	2833									
total pregnant women eligible for 18-22 week	57 %	99 %	1 %	27 %	26 %					
	number atter	BP measure	High	Refer						
4312	2467	2434	15	4						
				No test				True Pos	obs Pos	Man
				11				27	15	4
			Normal							
			2419					56 %	56 %	27 %
		No BP								
		33								
	not attend 20 week			s2%	Prop Pos2					
	1845		0 %	83 %	30 %	0 %				
			Prop Pos 1	s2%	Prop Pos2	M				
			0 %	80 %	13 %	0 %				
	Attend %	S1%	Prop Pos 1	S2%	Prop Pos2	M				
total pregnant women eligible for 24-28 week visit	60 %	98 %	0 %	100 %	100 %	0 %				
	number atter	BP measure	High			Refer				
4312	2592	2550	2	2	2	0				
						not referred				
						2		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		5,5	3,0	0
			10	8	1	0				
						not referred		55 %	49 %	0 %
						1				
					Negative					
					7					
				No urine protein						
				2						
			Normal							
			2538							
		No BP								
		42								
	not attend 24-28			s2%	Prop Pos2					
	1720		0 %	59 %	20 %	50 %				
			Prop Pos 1	s2%	Prop Pos2	M				
			1 %	53 %	0 %	50 %				
	Attend %	S1%	Prop Pos 1	S2%	Prop Pos2	M				
total pregnant women eligible for 32 week visit	49 %	98 %	0 %	100 %	100 %	#DIV/0!				
	number atter	BP measure	High			Refer				
4311	2094	2059	2	2	2	1				
						not referred				
						1		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		4,2	2,0	1
			15	8	0	0				
						not referred		48 %	48 %	50 %
						0				
					Negative					
					8					
				No urine protein						
				7						
			Normal							
			2042							
		No BP								
		35								
	not attend 32 week			s2%	Prop Pos2					
	2217		1 %	59 %	41 %	67 %				
			Prop Pos 1	s2%	Prop Pos2	M				
			2 %	52 %	19 %	67 %				
	Attend %	S1%	Prop Pos 1	S2%	Prop Pos2	M				
total pregnant women eligible for 36 week visit	44 %	98 %	0 %	100 %	100 %	67 %				
	number atter	BP measure	High			Refer				
4305	1903	1873	6	6	6	4				
						not referred				
						2		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		27,2	9,0	6
			31	16	3	2				
						not referred		33 %	44 %	67 %
						1				
					Negative					
					13					
				No urine protein						
				15						
			Normal							
			1836							
		No BP						Overall Pos	Overall Obs	Overall Mana
		30						243,4	114,0	85,0
	Not attend 36 week									
	2402							47 %		75 %
Overall screening proportion										
47 %										
Overall management proportion										
75 %										
	Appropriate screening and management of hypertension									
List Input	35 %									

Hypertension – paper-based clinical records data



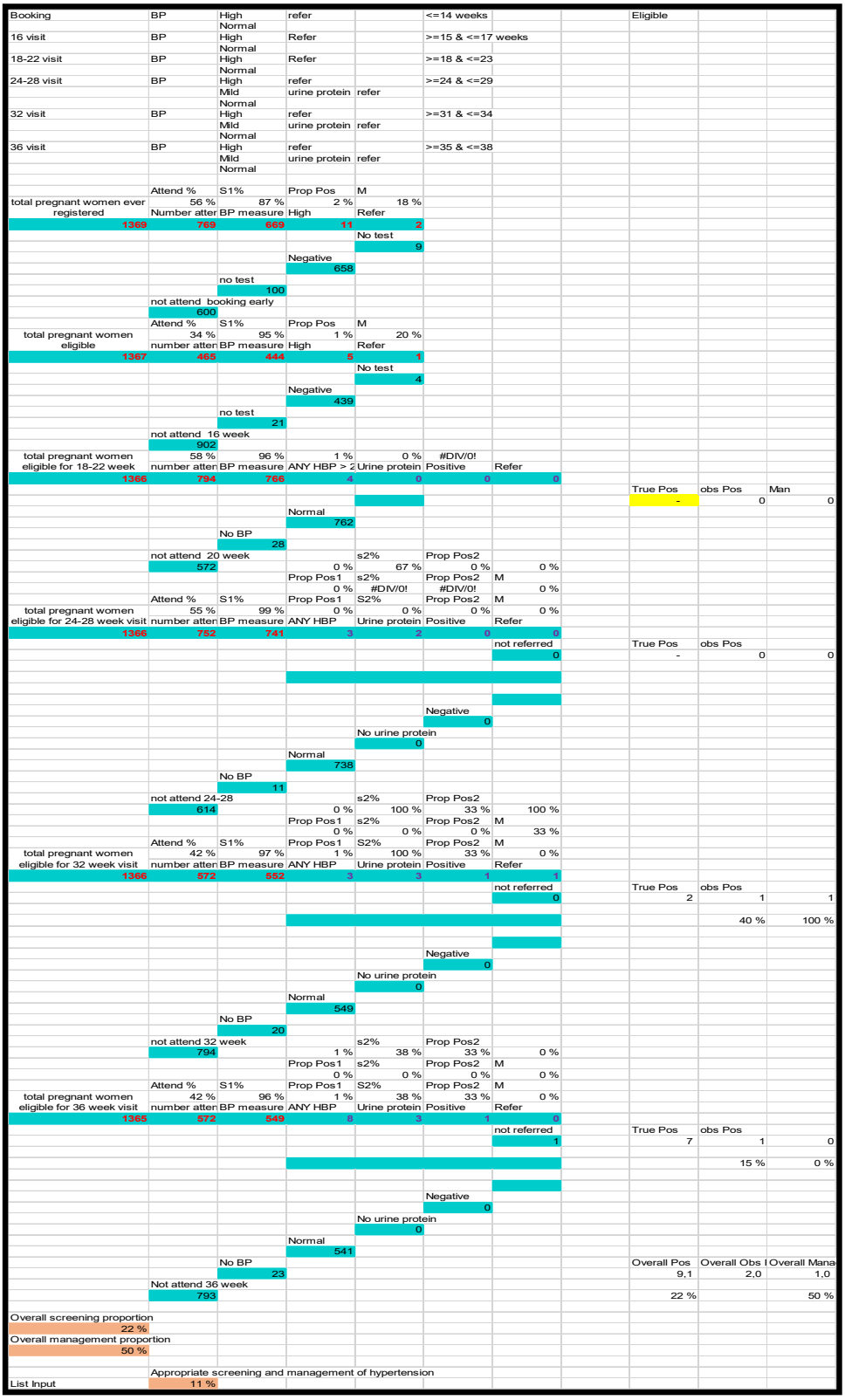
Booking	BP	High	refer		<=14 weeks			Eligible		
		Normal								
16 visit	BP	High	Refer		>=15 & <=17 weeks					
		Normal								
18-22 visit	BP	High	Refer		>=18 & <=23					
		Normal								
24-28 visit	BP	High	refer		>=24 & <=29					
		Mild	urine protein	refer						
		Normal								
32 visit	BP	High	refer		>=31 & <=34					
		Mild	urine protein	refer						
		Normal								
36 visit	BP	High	refer		>=35 & <=38					
		Mild	urine protein	refer						
		Normal								
	Attend %	S1%	Prop Pos	M						
total pregnant women ever	56 %	87 %	2 %	18 %						
registered	Number atter	BP measure	High	Refer						
1369	769	669	11	2						
				No test				True Pos	obs Pos	Man
				9				23	11	2
			Negative							
			658					49 %	49 %	18 %
		no test								
		100								
	not attend	booking early								
	600									
	Attend %	S1%	Prop Pos	M						
total pregnant women	34 %	95 %	1 %	20 %						
eligible	number atter	BP measure	High	Refer						
1367	465	444	5	1						
				No test				True Pos	obs Pos	Man
				4				15	5	1
			Negative							
			439					32 %	32 %	20 %
		no test								
		21								
	not attend	16 week								
	902									
total pregnant women	58 %	96 %	1 %	0 %						
eligible for 18-22 week	number atter	BP measure	High	Refer						
1366	794	765	6	0						
				No test				True Pos	obs Pos	Man
				6				11	6	0
			Normal							
			760					56 %	56 %	0 %
		No BP								
		28								
	not attend	20 week		s2%	Prop Pos2					
	572		0 %	67 %	0 %	0 %				
			Prop Pos1	s2%	Prop Pos2	M				
			0 %	67 %	0 %	0 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women	55 %	99 %	0 %	0 %	0 %	0 %				
eligible for 24-28 week visit	number atter	BP measure	High			Refer				
1366	752	741	0	0	0	0				
						not referred				
						0		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		-	-	0
			3	2	0	0			0	
						not referred		0 %	0 %	0 %
						0				
					Negative					
					2					
				No urine protein						
				1						
			Normal							
			738							
		No BP								
		11								
	not attend	24-28		s2%	Prop Pos2					
	614		1 %	100 %	71 %	100 %				
			Prop Pos1	s2%	Prop Pos2	M				
			1 %	0 %	0 %	100 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women	42 %	97 %	1 %	100 %	100 %	0 %				
eligible for 32 week visit	number atter	BP measure	High			Refer				
1361	572	552	4	4	4	4				
						not referred				
						0		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		9,9	4,0	5
			3	3	1	1			5	
						not referred		41 %	41 %	100 %
						0				
					Negative					
					2					
				No urine protein						
				0						
			Normal							
			545							
		No BP								
		20								
	not attend	32 week		s2%	Prop Pos2					
	789		1 %	60 %	67 %	50 %				
			Prop Pos1	s2%	Prop Pos2	M				
			1 %	0 %	0 %	50 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women	42 %	96 %	1 %	100 %	100 %	0 %				
eligible for 36 week visit	number atter	BP measure	High			Refer				
1359	572	549	4	4	4	2				
						not referred				
						2		True Pos	obs Pos	
			Mild	Urine protein	Positive	Refer		9,9	4,0	2
			6	2	0	0			4	
						not referred		40 %	40 %	50 %
						0				
					Negative					
					2					
				No urine protein						
				4						
			Normal							
			539							
		No BP						Overall Pos	Overall Obs	Overall Mana
		23						68,4	30,0	10,0
	Not attend	36 week								
	787							44 %		33 %
Overall screening proportion										
44 %										
Overall management proportion										
33 %										
	Appropriate screening and management of hypertension									
List Input	15 %									

Pre-eclampsia – eRegistry data



Booking	BP	High	refer		<=14 weeks			Eligible		
		Normal								
16 visit	BP	High	Refer		>=15 & <=17 weeks					
		Normal								
18-22 visit	BP	High	Refer		>=18 & <=23					
		Normal								
24-28 visit	BP	High	refer		>=24 & <=29					
		Mild	urine protein	refer						
		Normal								
32 visit	BP	High	refer		>=31 & <=34					
		Mild	urine protein	refer						
		Normal								
36 visit	BP	High	refer		>=35 & <=38					
		Mild	urine protein	refer						
		Normal								
	Attend %	S1%	Prop Pos	M						
total pregnant women ever	57 %	99 %	2 %	97 %						
registered	Number atter	BP measure	High	Refer						
4388	2480	2450	61	59						
				No test						
				2						
			Negative							
			2389							
		no test								
		30								
	not attend	booking early								
	1906									
	Attend %	S1%	Prop Pos	M						
total pregnant women	35 %	98 %	2 %	63 %						
eligible	number atter	BP measure	High	Refer						
4327	1494	1457	24	15						
				No test						
				9						
			Negative							
			1443							
		no test								
		27								
	not attend	16 week								
	2833									
total pregnant women	57 %	99 %	0 %	78 %	14 %					
eligible for 18-22 week	number atter	BP measure	ANY HBP > 2	Urine protein	Positive		Refer			
4312	2467	2434	9	7	1		1			
								True Pos	obs Pos	Man
								2	1	1
			Normal							
			2425						44 %	100 %
		No BP								
		33								
	not attend	20 week		s2%	Prop Pos2					
	1845		0 %	83 %	10 %		0 %			
			Prop Pos1	s2%	Prop Pos2		M			
			0 %	#DIV/0!	#DIV/0!		0 %			
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2		M			
total pregnant women	60 %	98 %	0 %	0 %	10 %		0 %			
eligible for 24-28 week visit	number atter	BP measure	ANY HBP	Urine protein	Positive		Refer			
4312	2592	2550	12	10	1		0			
								True Pos	obs Pos	
								2	1	0
									49 %	0 %
					Negative					
					9					
				No urine protein						
				0						
			Normal							
			2538							
		No BP								
		42								
	not attend	24-28		s2%	Prop Pos2					
	1720		0 %	50 %	0 %		#DIV/0!			
			Prop Pos1	s2%	Prop Pos2		M			
			0 %	0 %	0 %		0 %			
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2		M			
total pregnant women	49 %	98 %	1 %	50 %	0 %		0 %			
eligible for 32 week visit	number atter	BP measure	ANY HBP	Urine protein	Positive		Refer			
4312	2094	2059	16	8	0		0			
							not referred	True Pos	obs Pos	
							0	-	0	0
					Negative					
					0					
				No urine protein						
				0						
			Normal							
			2043							
		No BP								
		35								
	not attend	32 week		s2%	Prop Pos2					
	2218		1 %	55 %	22 %		50 %			
			Prop Pos1	s2%	Prop Pos2		M			
			0 %	0 %	0 %		6 %			
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2		M			
total pregnant women	44 %	98 %	2 %	55 %	22 %		0 %			
eligible for 36 week visit	number atter	BP measure	ANY HBP	Urine protein	Positive		Refer			
4310	1903	1873	33	18	4		2			
							not referred	True Pos	obs Pos	
							2	17	4	2
									24 %	50 %
					Negative					
					0					
				No urine protein						
				0						
			Normal							
			1840							
		No BP						Overall Pos	Overall Obs	Overall Mana
		30						21,2	6,0	3,0
	Not attend	36 week								
	2407							28 %		50 %
Overall screening proportion										
28 %										
Overall management proportion										
50 %										
	Appropriate screening and management of hypertension									
List Input	14 %									

Pre-eclampsia – paper-based clinical records data



Booking	BP	High	refer		<=14 weeks			Eligible		
		Normal								
16 visit	BP	High	Refer		>=15 & <=17 weeks					
		Normal								
18-22 visit	BP	High	Refer		>=18 & <=23					
		Normal								
24-28 visit	BP	High	refer		>=24 & <=29					
		Mild	urine protein	refer						
		Normal								
32 visit	BP	High	refer		>=31 & <=34					
		Mild	urine protein	refer						
		Normal								
36 visit	BP	High	refer		>=35 & <=38					
		Mild	urine protein	refer						
		Normal								
	Attend %	S1%	Prop Pos	M						
total pregnant women ever registered	56 %	87 %	2 %	18 %						
	Number atter	BP measure	High	Refer						
1369	769	669	11	2						
				No test						
				9						
			Negative							
			658							
		no test								
		100								
	not attend	booking early								
	600									
	Attend %	S1%	Prop Pos	M						
total pregnant women eligible	34 %	95 %	1 %	20 %						
	number atter	BP measure	High	Refer						
1367	465	444	5	1						
				No test						
				4						
			Negative							
			439							
		no test								
		21								
	not attend	16 week								
	902									
total pregnant women eligible for 18-22 week	58 %	96 %	1 %	0 %	#DIV/0!					
	number atter	BP measure	ANY HBP > 2	Urine protein	Positive	Refer				
1366	794	768	4	0	0	0				
								True Pos	obs Pos	Man
								-	0	0
			Normal							
			762							
		No BP								
		28								
	not attend	20 week		s2%	Prop Pos2					
	572		0 %	67 %	0 %	0 %				
			Prop Pos1	s2%	Prop Pos2	M				
			0 %	#DIV/0!	#DIV/0!	0 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women eligible for 24-28 week visit	55 %	99 %	0 %	0 %	0 %	0 %				
	number atter	BP measure	ANY HBP	Urine protein	Positive	Refer				
1366	752	741	3	2	0	0				
						not referred		True Pos	obs Pos	
						0		-	0	0
					Negative					
					0					
				No urine protein						
				0						
			Normal							
			738							
		No BP								
		11								
	not attend	24-28		s2%	Prop Pos2					
	614		0 %	100 %	33 %	100 %				
			Prop Pos1	s2%	Prop Pos2	M				
			0 %	0 %	0 %	33 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women eligible for 32 week visit	42 %	97 %	1 %	100 %	33 %	0 %				
	number atter	BP measure	ANY HBP	Urine protein	Positive	Refer				
1366	572	552	3	3	1	1				
						not referred		True Pos	obs Pos	
						0		2	1	1
									40 %	100 %
					Negative					
					0					
				No urine protein						
				0						
			Normal							
			549							
		No BP								
		20								
	not attend	32 week		s2%	Prop Pos2					
	794		1 %	38 %	33 %	0 %				
			Prop Pos1	s2%	Prop Pos2	M				
			0 %	0 %	0 %	0 %				
	Attend %	S1%	Prop Pos1	S2%	Prop Pos2	M				
total pregnant women eligible for 36 week visit	42 %	96 %	1 %	38 %	33 %	0 %				
	number atter	BP measure	ANY HBP	Urine protein	Positive	Refer				
1365	572	549	8	3	1	0				
						not referred		True Pos	obs Pos	
						1		7	1	0
									15 %	0 %
					Negative					
					0					
				No urine protein						
				0						
			Normal							
			541							
		No BP						Overall Pos	Overall Obs I	Overall Mana
		23						9,1	2,0	1,0
	Not attend	36 week								
	793							22 %		50 %
Overall screening proportion										
22 %										
Overall management proportion										
50 %										
	Appropriate screening and management of hypertension									
List Input	11 %									

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