

Consistency of denominator data in electronic health records in Australian primary healthcare services: enhancing data quality

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Abstract. The quality of data derived from primary healthcare electronic systems has been subjected to little critical systematic analysis, especially in relation to the purported benefits and substantial investment in electronic information systems in primary care. Many indicators of quality of care are based on numbers of certain types of patients as denominators. Consistency of denominator data is vital for comparison of indicators over time and between services. This paper examines the consistency of denominator data extracted from electronic health records (EHRs) for monitoring of access and quality of primary health care. Data collection and analysis were conducted as part of a prospective mixed-methods formative evaluation of the Commonwealth Government's Indigenous Chronic Disease Package. Twenty-six general practices and 14 Aboriginal Health Services (AHSs) located in all Australian States and Territories and in urban, regional and remote locations were purposively selected within geographically defined locations. Percentage change in reported number of regular patients in general practices ranged between -50% and 453% (average 37%). The corresponding figure for AHSs was 1% to 217% (average 31%). In approximately half of general practices and AHSs, the change was $\geq 20\%$. There were similarly large changes in reported numbers of patients with a diagnosis of diabetes or coronary heart disease (CHD), and Indigenous patients. Inconsistencies in reported numbers were due primarily to limited capability of staff in many general practices and AHSs to accurately enter, manage, and extract data from EHRs. The inconsistencies in data required for the calculation of many key indicators of access and quality of care places serious constraints on the meaningful use of data extracted from EHRs. There is a need for greater attention to quality of denominator data in order to realise the potential benefits of EHRs for patient care, service planning, improvement, and policy. We propose a quality improvement approach for enhancing data quality.

Additional keywords: clinical information systems, electronic data extraction, primary health care, quality indicators, quality of data.

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Introduction

Increasing expectations regarding efficiency, effectiveness and quality of care are highlighting the need for better information on the care provided to individual patients and to populations. The expanding use of electronic health records (EHRs) has the potential to overcome some of the challenges of gathering data in the primary healthcare setting, and there is international interest in potential benefits of EHRs for patient care and for secondary analysis: outcome measurement, quality improvement, public health surveillance and research (Majeed *et al.* 2008).

Systematic reviews show a large gap between postulated and demonstrated benefits of EHRs. Many claims are made regarding a wide range of potential benefits, but there is little evidence to substantiate these claims (Black *et al.* 2011; Crosson *et al.* 2012; Lau *et al.* 2012).

An important constraint of EHRs for delivering on their potential is the quality of the data in the EHRs. Recent

international research in countries with a relatively long history of use of EHRs has demonstrated the poor reliability of data extracted from EHRs (Parsons *et al.* 2012; Barkhuysen *et al.* 2014). While there is a lack of standardised methods for assessing quality of data in EHRs (Thiru *et al.* 2003), measurement theory refers to reliability and validity of data, with reliability being a 'precursor' of validity.

Reliability refers to the production of the same results on repeated collection, processing, storing and display of information (World Health Organization 2003). Reliability is a measure of stability of data, is assessed through comparison of rates and prevalence, and requires consistent denominator data (Thiru *et al.* 2003). So, assessment of consistency of denominator data is fundamental to assessment of data quality.

Many indicators of quality of care are based on numbers of certain types of patients as denominators. Reliable denominator data are required for the calculation of many indicators for

What is known about the topic?

- The quality of data derived from primary healthcare electronic systems has been subjected to little systematic analysis, especially in relation to the purported benefits and substantial investment in electronic information systems in primary care.

What does this paper add?

- We provide evidence of inconsistency in denominator data in many health services and propose a set of indicators for use within a quality improvement framework to enhance the quality of data in electronic health records.

monitoring and improving access and quality of care at any level (health service or practice populations, or populations at regional, State/Territory level). This paper examines the consistency of denominator data required for calculation of indicators of access and quality of care, as extracted from EHRs in general practices and Aboriginal Health Services (AHSs), the reasons for inconsistencies in the denominator data, and proposes a set of indicators for use within a quality improvement approach to enhance the quality of data in EHRs.

Methods

The Sentinel Sites Evaluation (SSE) of the Indigenous Chronic Disease Package (ICDP) provided a unique opportunity to assess the extent to which services are able to provide clinical indicator data that is of sufficient quality for programme monitoring or evaluation purposes (Bailie *et al.* 2013a). Between the middle of 2010 and early 2013, the SSE provided 6-monthly reports on the progress with implementation of the ICDP in geographically defined 'Sentinel Sites'. The evaluation framework for the ICDP specified the use of clinical indicator data to assess impact of the ICDP on quality of care and clinical outcomes, with specific reference to diabetes and coronary heart disease (CHD) (Urbis 2010). Over the course of the SSE, requests for clinical indicator data were made to 53 general practices and AHSs in 16 sites over five successive 6-monthly evaluation cycles. The AHSs included Community-Controlled and Government-managed health services. Services were offered a nominal fee for provision of clinical indicator data. The general practices that were approached were those that were identified by regional support organisations (such as Medicare Locals (ML)/Divisions of General Practice (DGP)) as having the capacity to provide clinical indicator data and an interest in Indigenous health. The general practices and AHSs used a variety of software systems and data extraction tools (the most common automated extraction used was the Pen Computing Clinical Audit Tool (PENCAT)) (Bailie *et al.* 2013b). Where necessary, the SSE team and regional support organisations provided support to health services to extract clinical indicator data from their EHRs, their quality improvement systems or from data reports prepared by the health services for other purposes. This paper presents further analysis of data that were reported in the appendix of the SSE

Final Report (Bailie *et al.* 2013b). The evaluation methods are described in detail in the SSE Final Report (Bailie *et al.* 2013a).

Data from more recent cycles were more complete, in terms of numbers of services that provided data and the number of indicators on which they provided data, and most services provided data for no more than two or three cycles, often with a gap between cycles. As a measure of consistency of the data provided, we therefore report on the percentage difference in the numbers provided by each service over a 6 or 12 month period. To calculate the percentage difference, the difference between the number reported in the most recent cycle for which data were provided and the number reported in the preceding one or two cycles (depending on which cycle data were provided, and using the larger difference if data were provided for both preceding cycles) were used. For example, in the first listed GP in Appendix 1, the number of regular patients in the most recent cycle was 9407 and the percentage difference between this and the previous 6 or 12 months is 453%. The calculation was: $(9407-1701)/1701$ (where 1701 was the number of regular patients reported in the previous 6 or 12 months). The resulting figure is expressed as a percentage to provide a standard measure and to enable comparison between services. For the same service, the percentage difference for Indigenous patients with a diagnosis of diabetes was 400%; the calculation used for this was $(5-1)/1$, (where 1 was the number of Indigenous patients with a diagnosis of diabetes reported in the previous 6 or 12 months). This approach maximised the use of available data, given that very few services provided data for three or more successive cycles.

We focus on three categories of denominator data that are required for the calculation of key indicators that were specified in the evaluation framework:

- 'Regular' patients, based on the definition of 'regular' (or 'active'), as used by each service.
- Regular patients (or all patients if data for regular patients was not available) with a diagnosis of: (a) diabetes and (b) CHD.
- Patients identified as Indigenous.

Qualitative data on the ability of services to provide clinical indicator data were gathered through discussion with health service staff in the course of obtaining clinical indicator data for the evaluation, and through in-depth interviews with 24 key informants in services and regional support organisations following the final evaluation cycle. The in-depth interviews aimed to explore barriers and enablers to providing reliable data through encouraging health service and relevant support staff to reflect on reasons for differences in numbers reported in different evaluation cycles. Particular effort was directed at understanding the reasons for the more substantial changes in reported data; this included follow-up interviews and specific enquiry regarding differences in the data reported for different evaluation cycles. Data from interview notes and audio recordings were thematically analysed to identify underlying reasons for the limited ability to provide consistent data over successive evaluation cycles. Data were initially organised according to similar concepts or ideas, and these were then grouped into common themes in relation to influences on quality of data; (1) in general; (2) on regular patients; (3) on patients with specific conditions; and (4) on Indigenous status of patients.

Ethical approval for the SSE was granted through the Department of Health and Ageing Ethics Committee, project number 10/2012.

Results

In response to the requests to provide clinical indicator data, of the 53 services approached, 40 services (26 general practices; 14 AHSs) provided clinical indicator data for at least one evaluation cycle. Almost all of these services provided data on the number of regular patients, number of patients identified as Indigenous and number of patients with a diagnosis of diabetes or CHD (Appendices 1 and 2), with only one general practice and one AHS not providing data on a few specific items.

Of the 26 general practices that provided data, 22 provided data that allowed assessment of difference over a 6 or 12 month period in the number of regular patients or the number of patients identified as Indigenous. The percentage change in regular patients ranged between -50% and 453% (average 37%). For nine of the 22 general practices, the change was $\geq 20\%$. The percentage change in the number of patients identified as Indigenous ranged between -59% and 304% (average 50%). For 15 of the 22 general practices, the change was $\geq 20\%$ (Fig. 1).

For the 14 AHSs, 10 provided data that allowed for assessment of the difference in regular patients, and nine provided data that allowed for assessment of the difference in patients identified as Indigenous. The percentage difference in regular patients ranged between 1% and 217% (average 31%; for six of the 10 AHSs, the difference was $\geq 20\%$). The difference in the number of patients identified as Indigenous ranged between -66% and 42% (average -6%; for five of the nine AHSs, the change was $\geq 20\%$; Fig. 2).

Approximately two-thirds of the 26 general practices provided data that allowed assessment of change in the reported numbers of patients with a diagnosis of diabetes (17 practices) and/or CHD (18 practices). For the 14 AHSs, the corresponding numbers were 12 and seven. For general practices, the percentage difference in patients with a diagnosis of diabetes ranged between -88% and 400% (average 87%; for 14 of the 17 general practices, the change was $\geq 20\%$), and the difference in patients with CHD ranged between -100% and 100% (average 14%; for 10 of the 18 general practices, the change was $\geq 20\%$; Fig. 3). For AHSs, the percentage difference in patients with diabetes ranged between 2% and 121% (average 32%; for five of the 12 AHSs, the change

was $\geq 20\%$), and the difference in patients with CHD ranged between 1% and 168% (average 46%; for three of the seven AHSs, the change was $\geq 20\%$; Fig. 3).

Interviews with health service and DGP/ML staff indicated that the changes in these important categories of denominator data could be attributed to a variety of interacting influences. It was surprisingly difficult in some instances to get clear or specific explanations for changes in reported data, including for some services that showed the most substantial changes. Several influences affected the general quality of data in EHRs, including variable levels of completeness of data, variable functional capability of different EHRs and health services switching between software systems. For each of these, there was a range of contributing factors (Table 1). There were also influences that were specific to certain categories of denominator data. Quality of data on the numbers of regular patients was affected by the lack of use of consistent definitions of 'regular' patient; difficulty in determining regular status for some patients; difficulties with data extraction; and inconsistent processes for updating of records regarding 'regular' patients. Quality of data on the numbers of patients with specific conditions was affected by missing or incorrectly entered information on patient diagnoses, the use of separate (often stand-alone) information systems for some purposes and difficulty with extracting data on

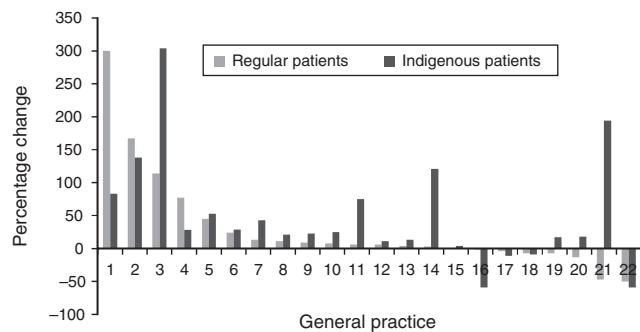


Fig. 1. Percentage change between data collection cycles: regular patients and patients identified as Indigenous for general practices. The number of regular patients for GP1 is 453 (truncated for presentation purposes).

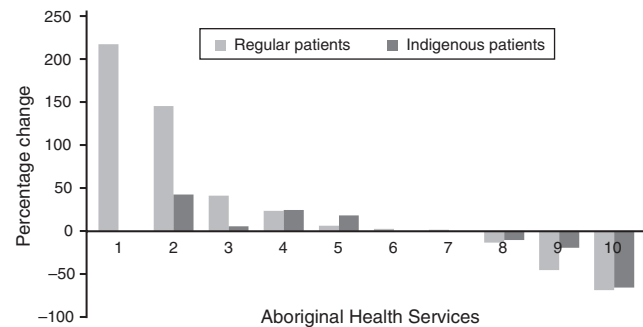


Fig. 2. Percentage change between data collection cycles: regular patients and patients identified as Indigenous for Aboriginal Health Services. Note: AHS 1, there was insufficient data for Indigenous patients to calculate the percentage change; AHS 6, no change was evident as the number of Indigenous patients stayed the same over cycles; and AHS 7, for regular patients, the percentage change was 1% (there was insufficient data for Indigenous patients to calculate the percentage change).

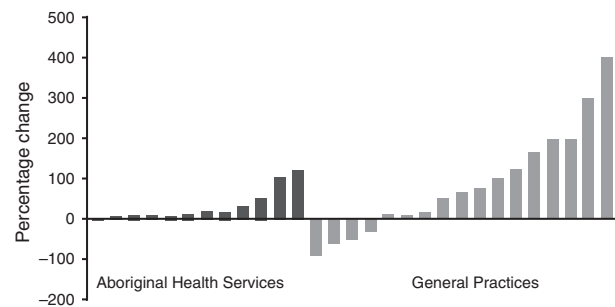


Fig. 3. Percentage change in the numbers of Indigenous patients on diabetes registers: Aboriginal Health Services and General Practices.

Table 1. Identified themes explaining the consistency of data required for reporting of clinical indicators

AHS, Aboriginal Health Service; APCC, Australian Primary Care Collaboratives; EHRs, electronic health records; GP, general practitioner; RACGP, Royal Australian College of General Practitioners

Themes	Exemplar quotes
General quality of data	
<p>Variable levels of completeness of data entered into EHRs, due to:</p> <ul style="list-style-type: none"> - inconsistent use of EHRs by some staff, with data entered into incorrect fields - limited skill among staff in the use of EHRs - limited staff training in the use of EHRs - EHRs not 'user-friendly' (or intuitive) for some staff - time pressures for key staff to enter data (clinicians) 	<ul style="list-style-type: none"> • <i>Two of our available GPs were not using the drop down menus for diagnosis; they were just doing free text in the clinical notes so our extraction was not fully picking up the patients' details. We have now corrected this by providing some training to these GPs.</i> (General Practice, urban site) • <i>The software we use is not intuitive, and few staff have had proper training to use it.</i> (AHS, regional site) • <i>It's a select group of staff that use the < EHR > (mainly clinical) and some are better than others at using it.</i> (AHS, regional site) • <i>I believe most of the clinical staff are familiar with our system. There is lots of training that happens on the job. GPs are sometimes time-poor so it can be difficult for them.</i> (AHS, urban site) • <i>The APCC report indicates 35 000 active patients but in reality we have around 11 000; there is something wrong with the way that the < name of extraction tool > extracts data from Medical Director. Medical Director indicates that we have around 11 000 active patients.</i> (General Practice, regional site) • <i>The number of all patients was artificially high in the first report (cycle 4) but we adjusted the filter on the < extraction tool > – this had the affect of removing all our non-regular patients and hence we had a drop of ~400 in the total number. We had many conversations with < name of EHR developer > and < name of EHR system > to get it right. < name of extraction tool > can only extract data from certain places in < name of EHR system > unlike most other < EHR >.</i> (AHS, regional site) • <i>We are still trying to address why the < name of extraction tool > is extracting data from archived patients.</i> (AHS, regional site) • <i>On line services report is also uploaded to < name of web portal >. We do have an issue with reports from < name of EHR system > not matching reports from < name of extraction tool > . . . we are not sure why there appears to be a difference in the data and neither are the IT providers.</i> (AHS, regional site) • <i>Cycle 4 data was not a good record. . . this was when we had changed over the patient information system (from Medical Director to Best Practice) and were given the < name of extraction tool > for the first time to upload our data into < name of web portal >. It overstated our number of active patients.</i> (AHS, regional site) • <i>Since we changed our EHR we are updating our patient information, as we noticed that quite a few of our patients are not identified.</i> (AHS, regional site)
<p>Variable functional capability of EHRs, due to:</p> <ul style="list-style-type: none"> - variable compatibility of different extraction tools with different EHRs - variable requirements of extraction tools with different EHRs - variable capability of staff in using extraction tools - difficulty with use of filters to extract data 	
<p>Changes of software systems by practices and difficulty with complete and accurate migration of data from old to new systems</p>	
Quality of data on regular patients	
<p>Lack of consistent application of active or regular patient definition or changes in definition used</p>	<ul style="list-style-type: none"> • <i>We have recently done a major clean up of our files and removed any patient who has not been here in the last 5 years. We only take out those patients (both Aboriginal and non-Aboriginal) as we were re-activating too many because our population is quite transient.</i> (General Practice, urban site)
<p>Difficulty in accurately classifying transient patients, regular visitors and patients travelling to access AHS</p>	
<p>Processes not in place to 'deactivate' or 'archive' records of patients who do not fit the definition of regular/active patients</p>	<ul style="list-style-type: none"> • <i>Once we manage to sort out our extraction of regular patient numbers we can move forward.</i> (AHS, regional site) • <i>The lists that we create using the < name of extraction tool > is still drawing from around 13000 patients (archived and new) so we are currently working with < name of EHR system > to update our regular patient data.</i> (AHS, regional site)
<p>Difficulty with extracting data for regular patients as opposed to all patients, including transient patients or visitors, at least partly due to use of hybrid systems</p>	<ul style="list-style-type: none"> • <i>I have developed an Excel spreadsheet to keep track of registered patients as we can't use recall and reminder functions in the patient information system. . . The practice has a hybrid system of paper and electronic . . . one GP refuses to use computers.</i> (AHS, urban site)
<p>Accreditation requirements and quality improvement programs provide motivation and mechanisms to improve data quality</p>	<ul style="list-style-type: none"> • <i>We have several accreditation processes and this is one of the motivations behind our continual updating and data cleaning. I do < name of QI support system > audits and regularly ask staff to check patient lists to make sure patients that are not still 'regular' are archived. We can also do automatic archiving but I think that staff doing the audit manually is much more accurate.</i> (AHS, urban site)

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Table 1. (continued)

Themes	Exemplar quotes
	<ul style="list-style-type: none"> • <i>We are cleaning up the 'non-active' patients. This process has been partly prompted by accreditation. (AHS, urban site)</i>
<p>Quality of data on patients with specific conditions</p> <p>Missing or incorrectly entered data on patient diagnoses, including use of free text in progress notes rather than use of correct data fields</p> <p>Separate computer- or paper-based systems (or 'hybrid' systems) used for various purposes, including 'disease registers' and managing care related to and billing for incentive payments</p>	<ul style="list-style-type: none"> • <i>We have been doing a diabetes patient register check . . . though this has to be done manually as a lot of information is contained in notes that the < name of extraction tool > will not pick up. We have a dedicated staff member that comes in every Wednesday and is looking through the files. (General Practice, regional site)</i> • <i>We are using an Excel spreadsheet to manage the process [of PIP registration i.e. identification, chronic disease and recalls] as previously when had both Ferret and Medical Director the recall list was not functioning as it was too messy and needed cleaning up and also there were challenges with the Indigenous status staying in the clinical information system. (AHS, regional site)</i> • <i>We don't use chronic disease registers. We recall patients to come back in from the spreadsheet not the information system. (AHS, regional site)</i>
<p>Quality of data on Indigenous patients</p> <p>Incomplete or inaccurate recording of Indigenous status by reception/administration staff</p> <p>Perceptions among some staff of the reluctance of Indigenous people to identify, and difficulty for some staff in asking about Indigenous status</p> <p>Expectations of cultural awareness training in improving identification</p>	<ul style="list-style-type: none"> • <i>I think it's partly that staff have not been recording it in the PIRS so when we do the extraction it shows a lot of patients as 'Not recorded'. (AHS, urban site)</i> • <i>We have a high turnover of staff at the practices so it's a constant job to educate the front-line staff about the importance of identification. (Medicare Local, regional site)</i> • <i>The practices are aware that patient identification is part of their RACGP accreditation and have been working towards better identification. However, I believe that there is a significant proportion of Aboriginal patients that do not want to identify. My understanding is that the 4 practices that have provided data all ask the question, however it is quite challenging. (Medicare Local, urban site)</i> • <i>. . . it's quite often a confidence issue with new staff. (Medicare Local, regional site)</i> • <i>It helped the practice staff to feel comfortable in asking the questions. The practice staff were pretty anti at the beginning, were concerned about any aggression at the front desk if the Aboriginality question is asked not only to the Aboriginal patients but to other patients as well. The practice staff learned how to ask the question more sensitively and ask everyone. (Practice manager, general practice, urban site)</i> • <i>As we get cultural awareness training into the practices this will hopefully improve identification. Reception staff are often very young and inexperienced. (Medicare Local, regional site)</i> • <i>We have only recently updated our patient information. This was motivated by the fact that we were due for accreditation and one of the criteria is that we identify Aboriginal and Torres Strait Islander patients. (General Practice, regional site)</i> • <i>The standard for RACGP accreditation 4th edition has motivated our practice to be more diligent in identifying Aboriginal and Torres Strait Islander patients. (General Practice, regional site)</i>
<p>Accreditation requirements provide motivation and mechanisms to improve data quality.</p>	<ul style="list-style-type: none"> • <i>The standard for RACGP accreditation 4th edition has motivated our practice to be more diligent in identifying Aboriginal and Torres Strait Islander patients. (General Practice, regional site)</i>

specific groups of patients (including those with a particular diagnosis or those identified as Indigenous). Quality of data on 'Indigenous status' was affected by incomplete, unsystematic or inaccurate recording of Indigenous status; difficulties with data extraction; and concerns among staff that some Indigenous people were reluctant to identify. Accreditation requirements and quality improvement processes were identified as contributing to efforts to improve the quality of data, particularly in relation to identifying regular patients and Indigenous status. There were also expectations that cultural awareness training would

contribute to quality of data on Indigenous status. Illustrative quotes for each of these influences on quality of data are provided in Table 1.

The evaluation team's experience of obtaining clinical indicator data, and of supporting services to provide the data, showed varying and often low capability of health service staff to use available systems effectively. It was clear that this varying and low capability was a major underlying reason for the variable quality of data. In addition to inconsistency in data entry and variable capability to extract data for different purposes, few

services had systematic processes for cleaning or maintaining data quality, with most reporting their processes were 'ad hoc'. Many general practices were reliant on DGP/ML staff to assist with extraction of data for reporting purposes, but there was varying capability between DGPs/MLs in providing such support. The focus in some services appeared to be more on extracting data for reporting purposes, with limited understanding of the importance or value of ensuring the quality of the data, or use of data for learning and improvement of health service systems and quality of care.

Discussion

The denominator data that are available for the calculation of many clinical indicators shows substantial inconsistency for many individual primary healthcare services, and is therefore

unreliable for the calculation of indicators at regional, state or national levels. Our experience with supporting health service staff to provide data, the inconsistencies in the data provided between cycles and the limited ability of staff to provide coherent explanations for these inconsistencies, indicates that the inconsistencies in reported numbers are due primarily to limited capability of staff in many general practices and AHSs to accurately enter, manage, and extract data from EHRs. These factors mean the numerator data required for clinical indicators are also likely to be unreliable, which compounds the problem of poor denominator data.

As for studies of data quality in primary care internationally (Thiru *et al.* 2003), limitations of the present study include: (1) that the quality of the data reported in this study is likely to be better than for general practices and AHSs more generally in Australia. The general practices that provided clinical indicator

Table 2. Proposed indicators and suggested use for monitoring and guiding improvement of electronic health records
EHR, electronic health record; RACGP, Royal Australian College of General Practitioners

Proposed System Capability indicators	Quality improvement actions
1. Ability to generate an up-to-date, reliable, complete patient list. a. Are practice staff able to generate a list of all patients? b. Stability of numbers in list.	#1. Define and implement criteria for inclusion of patients on the practice register. #2. Monitor changes over time in the number of patients who meet the inclusion criteria. #3. Are there significant changes over time in the numbers (e.g. more than 5%) that cannot be explained by processes that the practice has used to update the list within the relevant time frame? #4. Changes over time in numbers or proportions that cannot be explained may indicate a technical problem with the EHR or a problem with the way the list has been generated. Such problems should be investigated and steps taken to address the underlying causes. Develop and apply a standard protocol for 'data cleaning'.
2. Ability to generate an up-to-date, reliable, complete list of regular/active patients. a. Are practice staff able to generate a list of regular/active patients? b. Are practice staff aware of the definition of a regular/active patient? What definition is used? Do practice staff know where to review this in the EHR? c. Proportion of patients who are identified as regular/active patients on the complete patient list. d. Stability of numbers of all regular/active patients.	#5. Use a standard definition and implement criteria for inclusion of regular/active patients for use on the practice register. #6. Is there a significant proportion of patients who do not have a record of whether they meet the inclusion criteria or not (e.g. more than 5 or 10%)? If so, this may indicate a need to improve the recording of regular patient status. Alternatively, there may be a technical problem with the EHR or a problem with the way the list has been generated. Such problems should be investigated and steps taken to address the underlying causes. #7. Monitor changes over time in the number and proportion of patients who meet the inclusion criteria. #8. Are there significant changes over time in the numbers or proportions (e.g. more than 5%) that cannot be explained by processes that the practice has used to update the list within the relevant time frame? #9. If so, follow #4 above.
3. Ability to generate an up-to-date reliable, complete list of patients with specific care needs (e.g. patients in certain age groups, sex, Indigenous patients). a. Stability of numbers of patients in specific groups (e.g. regular/active patients, patients with diabetes, etc.).	#10. Review the proportion of regular/active patients for whom the characteristic (e.g. age, sex, ethnicity) is not recorded. Apply the RACGP standard definition of Indigenous status. #11. Follow #6, #7, #8, #9 above.
4. Ability to generate an up-to-date, reliable, complete list of patients with priority conditions that require regular care (e.g. diabetes, coronary heart disease). a. Stability of numbers of regular/active patients with specific conditions.	#12. Review the proportion of regular/active patients with a coded diagnosis of selected conditions and check if it is within the expected range according to population prevalence overall and in particular, groups with specific care needs (e.g. patients in certain age groups, Indigenous patients). #13. Is the proportion of patients with a diagnosis of the selected conditions outside the expected range (e.g. by more than 5 or 10%)? If so, this may indicate a need to improve recording of diagnoses or identification of patients with these conditions. Alternatively, there may be a technical problem with the EHR or a problem with the way the list has been generated. Such problems should be investigated and steps taken to address the underlying causes. #14. Monitor changes over time in the proportion of regular/active patients with a coded diagnosis of selected conditions. #15. Follow #8 and #9 above.

data were identified by the local DGP or ML as those that were more likely to be able to provide good quality data and that had an interest in Indigenous health, and the AHSs in many of the sites were recognised to be relatively well organised and managed; (2) because of the small number of services that provided data regularly for three or more cycles, it was not possible to do more detailed meaningful analysis of change between cycles; and (3) the difficulty in some locations of identifying key informants in health services and support organisations who had knowledge and experience of the operation of EHRs over the time frame of the project. This study limitation is inherent in the study finding regarding limited staff capability in the effective use of EHRs, which is consistent with other research that identifies staff skills and confidence as being an important limitation on effective use of EHRs (Majeed *et al.* 2008; Kelly *et al.* 2009; Riley *et al.* 2010; Black *et al.* 2011; Coiera 2013).

In contrast to a World Health Organization guide on improving data quality for developing countries (World Health Organization 2003), Australian reports and resources relevant to the use of EHRs in primary health care do not clearly address the fundamental importance of reliable denominator data in health information. Few research studies in Australian primary health care have assessed the quality of the data generated by automatic data extraction tools; for those that have done this, it is generally a secondary objective and they do not assess the stability of denominators (Liljeqvist *et al.* 2011; Schattner *et al.* 2011; Peiris *et al.* 2013).

The relative lack of investment in training in the use of EHRs compared with the high cost and complexity of implementation of EHRs, has been highlighted in Australia and internationally (Spitzer 2009; Lynott *et al.* 2012; Coiera 2013). The limited evidence on the effectiveness of training in improving data quality in EHRs indicates that short-term, low-intensity training has limited impact (Maddocks *et al.* 2011). As for other areas of behaviour change and skills development, substantial improvements in data quality are likely to require more intensive training associated with other strategies that are specifically designed to overcome the barriers to improvement as relevant to local contexts (Kaplan *et al.* 2012).

We propose a set of indicators for use within a quality improvement framework for the purpose of ongoing assessment and improvement of health service EHRs, and the capability of health service staff to use these systems effectively for patient-centred care and for enhancing the quality of care for their service populations (Table 2). The quality improvement framework and indicators could be used to encourage, monitor and reward accurate reporting of indicators by services and could enhance development of EHRs at a regional and national level.

In order to increase the understanding of data quality issues and drive efforts to improve data quality more generally, reports on the use of EHRs and of data derived from EHRs should explicitly examine data quality and should be appropriately circumspect with regard to interpretation of data. The vital requirement of good quality data for realising the potential benefits of EHRs, the hazards of poor quality data and the importance of monitoring reliability of data in making the transition to EHRs have been highlighted in recent publications (Majeed *et al.* 2008; Greiver *et al.* 2012; Denham *et al.* 2013). More should be done to encourage accurate recording and

reporting of health data as a way of enhancing patient care, service planning and policy development. Even the top performers in quality and safety internationally do not rely fully on automated extraction of data from EHRs for performance improvement (Crawford *et al.* 2013). Testing and improving the validity and reliability of performance indicators has been identified as an important area for research (Klazinga *et al.* 2011), and more specific attention to data quality should contribute to a more realistic understanding of the challenges and to more effective and efficient strategies for implementation of EHRs (Black *et al.* 2011).

The demonstrated inconsistencies in denominator data as a fundamental aspect of data quality places serious constraints on the meaningful use of data extracted from EHRs. There is a need for greater attention to data quality in order to realise the potential benefits EHRs for patient care, service planning and improvement and policy.

Conflicts of interest

RB is the Scientific Director of One21seventy, a not-for-profit initiative to support continuous quality improvement in primary health care, and which uses audits of samples of clinical records as a way of overcoming poor reliability of denominator data.

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Appendix 1. Numbers of regular patients identified as Indigenous, patients with a diagnosis of diabetes or coronary heart disease (CHD) and the percentage difference in numbers between evaluation cycles, as obtained from general practices (GP)

Empty data cells indicate that required data were not provided or there was insufficient data

Service	No. of regular patients ^A	No. of patients identified as Indigenous ^A	Indigenous patients (% of all regular patients) ^A	No. of Indigenous patients with a diagnosis of diabetes ^A	% of regular patients with a diagnosis of diabetes ^B	Indigenous patients with a diagnosis of diabetes (% of all Indigenous patients) ^B	No. of Indigenous patients with a diagnosis of CHD ^A	% of regular patients with a diagnosis of CHD ^B	Indigenous patients with a diagnosis of CHD ^B	Indigenous patients with a diagnosis of CHD (% of all Indigenous patients) ^B	Regular patients	Indigenous patients	Percentage difference in numbers between evaluation cycles (6 or 12 months)	Indigenous patients with a diagnosis of diabetes	Indigenous patients with a diagnosis of CHD
GP	9407	128	1.4	5	2.7	2	0	0.5	0	0	453	83	400	—	—
GP	6348	23	0.4	4	4.3	1.5	0	1.8	0	0	77	28	300	—	—
GP	1640	28	1.7	3	—	3.5	4	—	6	—	6	75	200	100	100
GP	8028	583	7.3	41	3.7	13.9	25	3.6	8.7	4.3	167	138	164	19	19
GP	18 771	357	1.9	28	3.6	4.2	9	2	2.4	2.5	24	29	65	28.6	28.6
GP	42 666	998	2.3	96	1.7	13.6	34	0.8	9.7	3.4	8	25	52	78.9	78.9
GP	17 328	707	4.1	31	3.4	5.2	11	1.7	3.6	1.6	13	43	121	10	10
GP	8496	144	1.7	6	4.2	1.7	5	2	2.9	3.5	-47	148	100	66.7	66.7
GP	6066	110	1.8	6	4.1	2.4	5	2.4	3.4	4.5	-13	18	—	—	—
GP	35 175	36	0.1	2	2.4	0.2	2	1.8	0.3	5.6	—	—	—	—	—
GP	16 641	66	0.4	3	—	—	1	—	—	—	—	—	—	—	—
GP	11 985	389	3.2	7	2.5	2.3	3	1.3	2	0.8	45	53	75	50	50
GP	5154	106	2.1	5	4.7	2	1	3.3	0.6	0.9	6	11	—	-50	-50
GP	4467	42	0.9	2	2.2	2	4.8	0.6	3.6	2.4	-4	-11	-33	0	0
GP	3882	27	0.7	3	7.4	1	11.1	3.7	0.7	3.7	0.5	4	—	—	—
GP	9011	140	1.6	6	3.4	2	4.3	1.3	2.5	2.1	9	23	—	50	50
GP	10 102	105	1.0	3	2.1	1.4	2.9	0.5	2	1	114	304	200	—	—
GP	—	—	—	7	—	1.9	—	—	2.1	—	—	—	—	—	—
GP	11 632	480	4.1	13	5.4	2.1	2.7	1.6	2.7	1	-7	-9	—	0	0
GP	22 215	433	1.9	25	2.6	4.3	5.8	0.8	4	1.6	11	21	9	0	0
GP	29 483	259	0.9	2	1.8	0.4	0.8	0.9	0	0	4	13	-60	-100	-100
GP	8518	559	6.6	31	2.9	12.8	6	1	7	1.1	-7	17	15	0	0
GP	9472	42	0.4	1	2.4	0.4	2.4	1.8	1.1	4.8	3	121	-50	0	0
GP	3524	97	2.8	3	3.5	2.4	3.1	3.1	2.7	3.1	-50	-59	-88	-72.7	-72.7
GP	7603	106	1.4	23	6.8	4.4	21.7	4.9	1.6	5.7	-2	29	10	0	0
GP	3339	33	1.0	3	—	—	—	—	—	—	—	—	—	—	—
GP	25	25	25	26	22	24	22	22	24	22	22	22	17	18	18
Number with available data (n = 26)															
Mean (range)	12 438 (1640–42666)	239.9 (23–998)	2.1 (0.1–7.3)	14 (1–96)	3.5 (1.7–7.4)	3.7 (0.2–13.9)	6.2 (0.8–21.7)	1.9 (0.5–4.9)	2.9 (0–9.7)	2.4 (0–5.7)	36.8 (-50–453)	50.2 (-59–304)	87.1 (-88–400)	13.7 (-100–100)	13.7 (-100–100)

^AData presented are the most recent data provided and may be from any cycle.

^BData presented are from health services who provided data in the final evaluation cycle.

Appendix 2. Numbers of regular patients, patients identified as Indigenous, patients with a diagnosis of diabetes or coronary heart disease (CHD) and the percentage difference in numbers between evaluation cycles, as obtained from Aboriginal Health Services

Empty data cells indicate that required data were not provided or there was insufficient data to calculate indicators. AHS, Aboriginal Health Service and includes Aboriginal Community Controlled Health Organisations and Government Managed Health Services

Service	No. of regular patients ^A	No. of Indigenous patients identified as Indigenous ^A	Indigenous patients (% of all regular patients) ^A	No. of Indigenous patients with a diagnosis of diabetes ^A	% of regular patients with a diagnosis of diabetes ^B of all Indigenous patients ^B	No. of Indigenous patients with a diagnosis of CHD ^A	% of regular patients with a diagnosis of CHD ^B of all Indigenous patients ^B	% of Indigenous patients with a diagnosis of CHD ^B	Indigenous patients with a diagnosis of CHD (% of all Indigenous patients) ^B	Regular patients with a diagnosis of diabetes	Indigenous patients with a diagnosis of diabetes	Percentage difference in numbers between evaluation cycles (6 or 12 months)	Indigenous patients with a diagnosis of CHD with a diagnosis of CHD
AHS	3586	1661	46.3	106	5.9	42	2.5	46.7	2.5	-69	121	-66	167.7
AHS	5978	5043	84.4	280	-	172	5.6	-	3.4	-	6	-	-
AHS	9813	4097	41.8	204	2.6	117	5.0	87.3	2.9	217	2	-	-
AHS	7642	6804	89.0	724	-	318	-	-	-	2	0	0	5.9
AHS	2048	2161	105.5	150	-	48	-	-	-	1	9	-	4.3
AHS	6679	2906	43.5	228	5.7	89	7.8	66.9	3.1	6	11	18	38.3
AHS	3039	2158	71.0	292	9.8	65	13.5	94.2	3	41	5	42	103
AHS	2197	1017	46.3	67	-	80	10.5	94.1	6	23	17	24	1.3
AHS	1513	1339	88.5	140	10.0	27	15.8	-	-	-	102	-	-
AHS	1090	885	81.2	71	-	15	-	-	-	-	-	-	-
AHS	848	714	84.2	146	-	59	24.8	-	-	-46	32	-20	-
AHS	3091	2342	75.8	461	4.7	52	4.6	92.9	1.9	-14	9	-11	4
AHS	2905	2669	91.9	124	-	-	7.4	-	-	-	-	-	-
AHS	-	351	-	26	6	12	10	6	7	10	9	9	7
Number of AHSs with available data (n = 14)	3879	2439	73.0	216	6.5	90	10.1	80.4	3.3	30.6	32.3	-6.3	46.3
Mean (range)	(848-9813)	(351-6804)	(41.8-105.5)	(26-724)	(2.6-10.0)	(15-318)	(5.0-24.8)	(46.7-94.2)	(1.9-6.0)	(1-217)	(2-121)	(-66-42)	(1.3-167.7)

^AData presented are the most recent data provided (not necessarily from the same year for different services).

^BData presented are from health services that provided data in the final evaluation cycle.