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Determining immunisation coverage rates in primary health care practices: A simple goal but a complex task

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ABSTRACT

Purpose: To explore the quality of data recording by practices and identify issues to be considered and addressed before such data can be used as a continuous measure of immunisation delivery.

Methods: One hundred and twenty-four randomly selected general practices visited to measure immunisation coverage using the various practice management systems (PMS) in use. To capture all target children it was necessary to build two queries: one generated a list of all children aged between 6 weeks and 2 years who had been to the practice, regardless of enrolment status; the other asked dates and nature of all immunisations given. Each different PMS required a unique query to extract the necessary information.

Results: Variability encountered included different types and versions of PMS and operating systems; variable degree of staff technical competence with their PMS; proportion of enrolled children ranging from nearly 0 to 100%; lack of consistency of the nature and location of data entry and coding; and unreliability of dates relating to some vaccination events.

Recommendations: To improve recording of immunisation coverage we recommend a standard early age of registration and enrolment; standard definitions of the denominator and of immunisation delay; greater uniformity of PMS; improved staff training; intrinsic data quality checks; integration of PMS with changes in the immunisation schedule; incentives and interval electronic checks to improve data quality.

1. Introduction

1.1. *Immunisation coverage and timeliness in New Zealand*

Childhood immunisation is one of the most cost-effective activities in healthcare [1]. In New Zealand (NZ), although immunisation has eliminated polio and controlled tetanus and diphtheria, the full potential benefits to health that immunisation can provide have not been obtained. Measles epidemics continue to occur [2,3]. Pertussis incidence rates are 5–10 time higher than in the UK or the USA [4–6]. Pertussis hospital discharge rates have increased steadily since the 1960s with the average rate in the 2000s (5.8 per 100,000 person-years) being 50% greater than in the 1960s (3.8 per 100,000 person-years) [7].

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The principal reason for this unfulfilled promise is mediocre immunisation coverage and poor on-time delivery of the immunisation schedule.

Regarding coverage, national and regional surveys performed during the 1990s found that less than 60% of children were fully immunised by age 2 years [8,9]. A 2005 national survey showed some improvement but still only 77% of children had received all immunisations scheduled for the first 2 years of life [10].

The available data on the timeliness of immunisation delivery is even more concerning. Timeliness was assessed in the national and regional surveys from the 1990s. Fewer than 60% of children had received all three of the 6 weeks, 3 months, 5 months primary series [8,11] During the 1995–1997 pertussis epidemic delay in receipt of any of the three pertussis vaccine doses scheduled during the first year of life was associated with a five-fold increased risk of hospitalisation with pertussis [12].

1.2. *Immunisation schedule in New Zealand*

The NZ National Immunisation Schedule involves free vaccination for all children at ages 6 weeks, 3, 5 and 15 months, 4 and 11 years for protection against poliomyelitis, pertussis, tetanus, diphtheria, hepatitis B, *Haemophilus influenzae* type b, measles, mumps and rubella [10]. The target is 95% fully immunised by age 2 years [13]. A special immunisation programme for meningococcal B vaccine was also introduced in 2004. Initially a three-dose regime, a 4th dose was licensed in January 2006 for all infants who received their 1st dose before they were 6 months old.

Implementation of the majority of this schedule is conducted in the primary health care setting, chiefly administered by practice nurses and some general practitioners. Practices have kept age/sex registers of their patients for a number of decades, with precall/recall systems universally in place to maximise immunisation coverage. By 2004, 99% of NZ general practices were using a computerised practice management system (PMS) with electronic registration and recall of patients [14]. All major PMS (also known as electronic medical records) in NZ have the ability to collect and audit the immunisations given by the primary health care practice. The majority of practices now actively collect this information as part of their contractual requirements.

In contrast with the mediocre coverage evident in national and regional surveys, some primary care providers achieve much higher coverage rates. Independent practice associations in Christchurch and Rotorua have reported immunisation coverage of over 90% for 2-year-old children enrolled in the practices. Both these examples are from primary health care organisations strongly committed to achieving high immunisation coverage [15,16].

1.3. *Measurement of immunisation delivery in New Zealand using electronic data*

A key factor that has hampered the improvement in coverage has been the lack of any intrinsic mechanism for measuring coverage. The estimates of coverage from 1992, 1996 and 2005 were all from stand-alone separately funded one-off surveys.

Attempts have been made to estimate coverage based upon the electronic record of immunisations given. When general practitioners immunise a child, they claim a fee for this immunisation. During the 1990s national immunisation coverage was estimated from these data by dividing the number of claims for a vaccine by the total number of children of the appropriate age group (based upon census population data). Unfortunately several factors invalidate these estimates.

A 1999 review of the current deficits in immunisation surveillance noted that only 53% of general practitioners reported immunisation data electronically. As fee claims for immunisation were not made by some capitated practices, data from these practices were often not entered into the database. The data from some immunisation providers had to be entered manually, some provided summary data only and some did not report any data [17].

Recently a performance management programme was introduced into primary care with additional funding available to practices within many Primary Health Organisations (PHOs) if they improved their performance against targets. The first of the clinical indicators listed is '*children fully vaccinated by their 2nd birthday*' (numerator = total number of children who turned two in the reporting period and had received all immunisations from the National Childhood Immunisation Schedule due at 6 weeks, 3 months, 5 months and 15 months; denominator = number of enrolled 2 year olds as at end of reporting period) [18].

Patients enrolled with a PHO and registered at the practice are included in the PMS report of immunisation coverage. Prior to the implementation of the Primary Health Strategy [19] and the establishment of PHOs, individual practices kept an age/sex register of their patients. Once PHOs were set up, enrolment of a patient at a practice meant that the person enrolling intended to use this PHO provider (general practice or health service) as their normal provider of ongoing primary health care service [20]. People can be enrolled with only one PHO at any one time. Funding for the practice is allocated based on the enrolled population. Individuals seeking services from a provider within a PHO when they are not enrolled with the PHO nor registered with that provider are 'casual users'.

In order to determine whether the recent improvements on the electronic recording of immunisation delivery in primary care have improved immunisation outcomes, we conducted an audit of a random sample of primary care practices. The aim of this study was to explore the quality of data recording by the practices and identify the issues that need to be considered and addressed before such data can be used as a (potentially) continuous measure of immunisation delivery. This study is part of a larger project which sought to determine the contribution that health care system factors make to immunisation coverage in NZ by measuring immunisation coverage in practices, determining the practice characteristics associated with higher immunisation coverage, the associations between health professionals knowledge and attitudes towards immunisation and the immunisation coverage of their patients and the association between parental perceptions of quality of primary care received and immunisation coverage. Reporting the actual details of immunisation coverage is beyond the scope is this current paper.

2. Method

There were 517 practices available in the study region, 346 in Auckland and 171 in Midland involving approximately 1500 GPs. Two hundred and thirteen of these 517 practices were randomly selected, 108 (31%) of the Auckland practices and 105 (61%) of the Midland practices.

Using random numbers allocated to the complete list of practices in these regions, practices were recruited in random order with a phone call to the principal GP. A random sample of 125 practices, 75 from the Auckland region and 50 from the Midland region with over sampling of Māori practices in both regions was determined to be sufficient size to show statistical significance at the 5% level for a practice characteristic/health professional knowledge measure/quality measure associated with higher immunisation coverage if this characteristic/measure is present in 20–25% more of the practices with higher coverage.

Practices were approached in order of assigned random number, until 125 consented. Seven practices approached were deemed ineligible because they did not have a specific population of children whom they recalled and immunised (for example, a prison clinic). Researcher DY visited each of these practices and worked with staff and the PMS to measure the immunisation coverage. One practice was lost to follow-up (a server crash led to their inability to provide coverage data) leaving 124 recruited practices.

Every New Zealander has a unique identifier for health known as a National Health Index number (NHI). The data required to determine immunisation coverage are the child's NHI, the date of birth of each child cared for by the practice, date of enrolment at the practice, all vaccinations given to each child, the date that each vaccination was given and whether the vaccines were given at this practice or another practice. Use of the NHI number meant that anonymity could be preserved while being able to link children between practices.

The PMS used in the majority of the practices was Medtech-32, but other systems also in use were My Practice (previously called Next Generation and prior to that GPDat), Houston and Profile (for both PC and Mac computers).

At the onset of this project it was assumed that collection of immunisation coverage data would be a simple procedure using the PMS standard immunisation report tool. The requirement was to identify all children under the care of a practice aged $\geq$6 weeks and $\leq$2 years, determine all the scheduled vaccinations they had received and the dates when received. While it was recognised that PMS systems differed in their ability to be audited for specific data, it was planned access all types of PMS system in use.

Patients were expected to be easily identifiable through the existing system and each would have a unique identifier, the NHI. It was expected the age/sex register would also include the patient's ethnicity, according to the Statistics NZ definitions, although in reality these data were often absent.

Examination of the standard PMS reports revealed that it was not possible to accurately determine either receipt or timeliness of immunisations. The report merely identified whether a vaccine had been given or not (i.e. whether it was overdue), without the specific date of receipt. A PMS immunisation query therefore could not give information on timeliness of a vaccine, but merely the percentage of children who had received their vaccinations at the time of the date of the report. In some cases it also gave status such as given, declined or non-responder so creating uncertainty as to whether or not the vaccine had been given.

2.1. *Specifically designed queries*

In order to capture all the target children (aged between 6 weeks and 2 years) at a practice, including those who had not received any vaccinations, it was necessary to build two queries. One generated a list of all children aged between 6 weeks and 2 years who had been to the practice, regardless of enrolment status (the patient list), and the other asked the dates and nature of all immunisations given (the immunisation list).

It was therefore necessary to build specific queries for each of the PMS systems in use. There was considerable variation in the assistance received from the various software vendors. In some cases there was reliance on a single GP with the necessary technical knowledge. Some PMS installations (in some cases resulting from local setup issues) demonstrated considerable instability, 'crashing' frequently resulting in the loss of significant amounts of data that had been previously entered electronically.

Using the specific queries built for this project the DY extracted the patient and immunisation information in an anonymised format during a visit to the practice. Results from the patient list and the immunisation list were then merged. The quality of the data extracted from each query varied considerably, with some in a ready-to-use form and others requiring substantial work to generate a single line of data for each child.

A minority of practices are not updated with the latest version of their PMS software hence there were variations across versions of the same PMS as well as between PMSs. Furthermore, the operating system used by the practice can effect how the PMS runs—updated versions may be less compatible with an existing operating system. Because of the variation in information stored and reported on by different versions, each required a unique query (computer programme) to be written to extract the necessary information.

3. Results

We approached 205 randomly selected eligible practices to reach our target population of 125 practices (61% response rate). The main reason given by the 80 practices which declined to participate was time restraint. Many practices were particularly strapped for time because of a contemporaneous staged roll-out of a national meningococcal B vaccination programme. Comparisons were made between the recruited and declined practices using a number of practice characteristics including number of enrolees per practice, and the proportion of practice enrolees that were

Table 1 – PMS used by practices in the study

PMS	Auckland		Midland		Total	
	n	%	*n*	%	*n*	%
Medtech-32	53	76	42	78	95	77
GPDat/next generation	9	13	2	4	11	9
Profile for Windows	2	3	6	11	8	6
Profile for Mac	5	7	0	0	5	4
Houston	0	0	3	5	3	2
Own system	0	0	1	2	1	1
Paper practice	1	1	0	0	1	1
Total	70	100	54	100	124	100

high needs, were of different ethnic groups and different social deprivation quintiles. No significant differences which might contribute to selection bias of declining practices were detected.

The full range PMS encountered in our study are listed in Table 1. Practice staff seldom demonstrated full technical competence with their PMS system and many available features were not completely understood. The payment required for vendor support may be a barrier to up-skilling staff in this domain.

DY visited all enrolled practices and collected the data. Occasionally more than one visit was required (134 visits were required for 124 practices).

We encountered one practice that did not use a PMS system but relied on a manual age/sex register and paper patient files. The target children were identified manually from the age/sex register, their paper files reviewed and the relevant information entered into a spreadsheet. This was a labour-intensive process, but the data extracted was considered to have a high degree of accuracy.

3.1. *Considerations in query building*

3.1.1. *Patient status*

It was apparent that there are two sets of variables. The first records that the patient is either enrolled or not enrolled. This is recorded at the practice, although strictly it refers to enrolment with a PHO. The other set of variables includes a variety of possible options such as 'registered', 'casual', 'visitor' or 'transferred', 'died'. Only 57% of the children who were registered with a practice were enrolled with the PHO. This complexity was not able to be captured by the PMS audits reports and the specially designed query was necessary to extract appropriate results. This process was both time-consuming and expensive, and particular attention to each practice's method of enrolment was necessary to ensure data was accurate.

To capture all the target children cared for by the practice, the query had to include registered/not registered; enrolled/not enrolled, and casual/not casual. A huge variation in the proportion of children enrolled was discovered, from near zero to the majority being enrolled.

Different PMS had differing fields in which to enter immunisation data. Most PMS had a pre-determined list, but with the additional ability for practitioners to use free text and to edit the 'drop-down' list. This meant that entries such as 'hepB', 'Hep B' or 'Hepatitis B' could all be captured as different vaccines. There was also a lack of consistency as to where specific data was entered. For example there was often a free text 'notes' field in which it might be recorded that a specific vaccine was given, the type of needle used, or that a parent had declined a vaccine.

3.1.2. *Unreliability of dates*

In some patient records the date for receipt of vaccination was the same for the entire series—in other words, it might appear that the 6 weeks, 3 months and 5 months vaccines were all given on the same day. On investigation it was found that this was the date of entry, rather than the date the vaccine was given. For example, when a patient enrolled from another practice attended a different clinic, a provider might inform the system that the child's vaccines were up-to-date, but the actual dates of receiving each vaccine were not entered and probably not even known This is not strictly a data recording error but a system error that requires data transfer from elsewhere, such as from another computer, or at the least requires the PMS system to have an option of 'given elsewhere' without reporting a date.

There was also uncertainty around the source of these data—it was typically unclear whether the record that the child had received all vaccinations was based on a report from the mother or other caregiver, or was derived from previous practice records. In some cases, a date might be entered next to a specific vaccination, but this might be the date that the vaccine was declined or the date the vaccine was given—the distinction may or may not be determinable from another coded field or a free text field. In the *NextGeneration* and *Medtech* systems it was clearer to determine when a parent had declined, if this information had been entered. However, in the *NextGeneration* system the decline date could be the same for all immunisations.

Other data-specific issues included earlier dates listed for later immunisations, and dates that were clearly wrong—for example, dates for the MMR vaccine that would suggest that the child had received this during the first 6 months of life. The completeness of the immunisation data for all of the children was listed at each practice. An immunisation was only counted if an immunisation date was listed in the data field for each of the eight immunisation events shown. The percentage of all children for whom immunisations were recorded as given was approximately 70% for the 6 weeks immunisations, 60% for the 3 months immunisations, 55% for the 5 months immunisations and 20% for the 15 months immunisations. There was wide variability across the practices in the proportion of children for whom this data was recorded. This variability was even greater for the immunisations given in the first year of life compared with the 15 months immunisations. Dates were considered invalid if they were prior to the child's date of birth, the same or later than the date listed for a subsequent immunisation, or if there was no date listed for earlier doses of similar or identical vaccines. The detail of the different types of date data errors is shown in Table 2 along with the 2006 national immunisation schedule.

Table 2 – Wrong dates listed for immunisation

Wrong dates	Immunisation date recording errors	Percentage of listed immunisations with error Median (5th, 95th Centile)
Immunisations listed as given at same date	DTaP-IPV1–DTaP-IPV 2	5 (1, 20)
	DTaP-IPV 1–DTaP-IPV 3	3 (1, 18)
	DTaP-IPV 2–DTaP-IPV 3	4 (1, 25)
	DTaP-IPV 3–DTaP-Hib	2 (1, 13)
	Overall	11 (1, 69)
	Hib-Hep B 1–Hib-Hep B 2	2 (1, 13)
	Hib-Hep B 1–Hep B	4 (1, 21)
	Hib-Hep B 2–Hep B	3 (1, 19)
	Overall	10 (1, 58)
Earlier immunisations listed as given after later immunisations	DTaP-IPV 2 after DTaP-IPV 1	1 (1, 6)
	DTaP-IPV 3 after DTaP-IPV 1	1 (1, 4)
	DTaP-IPV 3 after DTaP-IPV 2	2 (1, 9)
	DTaP-Hib after DTaP-IPV 1	1 (1, 2)
	DTaP-IPV after DTaP-IPV 2	1 (1, 2)
	DTaP-Hib after DTaP-IPV 1	2 (1, 3)
	Overall	4 (1, 16)
	Hib-Hep B 1 after Hib-Hep B 2	2 (1, 6)
	Hib-Hep B 1 after Heb B	2 (1, 4)
	Hib-Hep B 2 after Hep B	2 (1, 8)
	Overall	3 (1, 15)
Subsequent but not earlier immunisations	DTaP-IPV 2 but not DTaP-IPV 1	1 (0, 10)
	DTaP-IPV 3 but not DTaP-IPV 1	1 (0, 16)
	DTaP-IPV 3 but not DTaP-IPV 2	3 (0, 15)
	DTaP-Hib but not DTaP-IPV 3	3 (0, 18)
	Overall	10 (0, 50)
	Hib-Hep B 2 but not Hib-Hep B 1	1 (0, 14)
	Hep B after Hib-Hep B 1	1 (0, 14)
	Hep B after Hib-Hep B 2 but not Hib-Hep B 1	1 (0, 12)
	Overall	4 (0, 39)

Age	Immunisation given		Special programme 2004–2006
National Schedule			
6 weeks	DTaP-IPV 1	Hib-Hep B	MeNZB 1
3 months	DTaP-IPV 2	Hib-Hep B	MeNZB 2
5 months	DTaP-IPV 3	Heb B	MeNZB 3
10 months			MeNZB 4
15 months	Hib (DTaP-Hib before 2006)	MMR	
4 years	DTaP-IPV 4	MMR	

Key—DtaP: Diptheria, tetanus and acellular pertussis vaccine; DTaP-IPV: Diptheria, tetanus, acellular pertussis and inactivated polio vaccine; DTaP-Hib: Diptheria, tetanus, acellular pertussis and *Haemophilus influenzae* type b vaccine; Hib-Hep B: *Haemophilus influenzae* type b and Hepatitis B vaccine; Heb B: Hepatitis B vaccine; MMR: Measles, mumps and rubella vaccine; MeNZB: Meningococcal B vaccine.

Table 3 – Possible Medtech-32 vaccine outcome codes

AG	Alternative given
CIS	Closed not required
CPI	Closed by provider
D	Declined
DEC	Declined elsewhere
DIC	Declined by individual
DMC	Medical contra-indication
DNI	Natural immunity
DPC	Declined by parent
E	Given elsewhere
G	Given
GE	Given elsewhere NZ
GO	Gone overseas
N	Not-given
NR	Non-responder
R	Refused
RE	Re-scheduled

3.1.3. *Establishing whether immunisations had been given*

MedTech-32 has a number of outcome fields for each vaccine (see Table 3) but these were not always accurately entered and different practices used various combinations of these codes. The other PMS systems did not have the same outcome codes. If parents declined vaccines for their children this information was sometimes reported in a 'notes' field but at other times in the body of the (free-text) clinical notes of the child, i.e. uncoded.

Children who had received their first vaccine 'elsewhere' needed to be entered for appropriate recall for their subsequent vaccines. Where all vaccinations have been declined, a practice would sometimes remove this child from the recall list, thus changing either the denominator or numerator, depending on how these numbers were derived.

There is also the issue that the 'non-responder' was handled differently between practices. For example, one practice sent out three recall letters, and then removed the child from the recall system if there has been no response. Another practice followed up non-responders with phone-calls and possible outreach. Children removed from the recall system may or may not still have the 'flag alert' function maintained on their record for possible opportunistic vaccination when they present for other problems.

A small number of children were identified who had actually been immunised although this was not picked up by the PMS query (sometimes because the information was entered in the clinical records part of the notes).

3.1.4. *Inconsistent date of recall*

Recall protocols were not consistent between practices. For example, recalls might be done monthly, three monthly or not at all and might include both children due or nearly due for vaccination as well as those overdue. All PMS have a built in recall system to generate an automatic list of overdue patients. This recall function can be modified by individual providers. Our researcher observed that many practices would rely partly on the PMS and partly on their personalised system for tracking children who were overdue. In addition, some practices relied on PHO data that did not always match with PMS data or would alter the recommended overdue date on their own PMS system. The recommended overdue dates for immunisation, as defined by the Ministry of Health, are the default dates across the PMS recall systems. However, with the ability to alter these dates, guidelines are not always followed.

3.1.5. *Unique identifiers*

Although the NHI number is a unique identifier, it was found that not all patients in a practice had this number entered. Because the extracted data needed to be anonymised, it was important that each patient had a unique identifier. *Medtech-32* generates its own unique number for patients, which can be used as an alternative unique identifier. Multiple and incomplete unique identifiers increase the potential for the same child to appear more than once on any practice patient list or on patient lists from different practices.

3.1.6. *Error analysis*

Once the queries were run at individual practices, considerable error analysis and data cleaning was required. For each practice we generated a merged file that linked the unique identifying data for each child with his or her immunisation record. For our purposes data extracted as one line per vaccination per child needed to be transformed to a single line of information per patient, with a check that the number of vaccines entered added up to the original number from the query data. Because of the variability of codes for specific vaccines, interpretation was required to determine which vaccine had been given. The principal investigator of the overall study (CG) adjudicated, on a case-by-case basis, if a vaccine had been given and, if so, which vaccine and when. Some practices had perfect data sets, some only had a few immunisations categorised as 'other' which needed to be individually determined by CG, and some practices had many in the 'other' category. Table 4 gives an example of data from one practice which required considerable review by CG to determine immunisation status. In this practice 269/2815 (9.5%) of recoded immunisation events were in the 'other' category.

With *Medtech-32*, it could be determined whether a date beside a vaccination event meant that it was given, had been

Table 4 – Example of immunisation data extracted from an individual practice

Vaccine	Number recorded
DTaP-IPV 1	302
DTaP-IPV 2	270
DTaP-IPV 3	227
Hib-Hep B 1	301
Hib-Hep B 2	270
Heb B	213
DTaP-Hib	87
MeNZB 1	294
MeNZB 2	262
MeNZB 3	217
MMR 1	103
Other[a]	269
Total immunisations	2815

Data extracted from practice #373.

[a] Required case-by-case review to determine immunisation status.

given elsewhere or declined, by checking the outcome codes. This feature was also available on the *NextGeneration* system, but seldom used by the practices. However, with the other PMS, this check was not always possible.

3.2. *Summary of immunisation coverage*

With the analysis limited to those children who are both registered and enrolled a median of 68–75% of children in each practice had received all of the immunisations due according to their age and the immunisation schedule. A median of 45% of children were delayed for at least one of the scheduled immunisations. For both of these measures of immunisation coverage the variance across practices was large.

Only for the 6 weeks and 3 months immunisations received by registered and enrolled children was the median coverage greater than 90% and this was only with the more liberal third dose assumption coverage estimate. With both estimates coverage fell progressively from the 6 weeks through to the 15 months immunisations. A median of approximately 70% of registered and enrolled children 15 months and older had received the 15 months DTaP-Hib and the MMR vaccines. The variance between practices in the proportion of children that had received each immunisation increased with immunisations due at successively older ages.

4. Discussion

This study reports many difficulties in ascertaining seemingly straightforward immunisation coverage data from the usual computerised PMS available in NZ in 2005–2006. With the introduction of PHOs in 2002 [21] came the requirement for patients to be enrolled with only one PHO at any time, usually at the level of the general practice or primary health clinic. The primary health care strategy focus shifted from providing first-line services to restore people's health when they were unwell to including service approaches directed towards improving and maintaining the health of the population [19]. Funding to PHOs is capitated, based on the enrolled population, with greater funding provided to populations seen to be of high need (Māori, Pacific people and those of lower socio-economic status). Patients enrolled with one practice who visit another doctor or health care providers are classified as 'casual' patients and are not required to be included in the immunisation coverage data figures.

The large variation in the proportion of children registered and enrolled largely resulted from an anomaly of the recently introduced capitated (an interesting alternative) funding system. Government subsidies via PHOs are for all enrolled children. Capitated general practices, which receive population-based bulk funding from the government for serving their patients, have to pay a 'clawback' fee when a patient registered with them attends another primary health services provider [22]. This is a significant problem for some practices, especially those with young children being seen by accident and medical or after-hours services, hence some practices chose to not enrol pre-school children because of the financial penalty this could incur.

The data quality issues we identified appear to be due to several factors. Firstly, they illustrate the well-known principle that end-users enter data in a format that may suit them while being quite unsuitable for 'meta-users'. Firstly there is diversity in both the quality of, and expertise in using electronic data management systems. Some of these systems appear to have been developed for alternative purposes, for example billing, and have subsequently been modified to try and also have the capacity to measure immunisation delivery. The variable degree to which each PMS is able to do this introduces errors that are often only apparent to someone familiar with a number of different PMS. Second there is a lack of a quality checking process both within the PMS and within the management of clinic staff entering these immunisation data. Third, despite almost all practices having a PMS, considerable issues persist with the accurate determination of both the denominator and the numerator in any estimate of practice coverage.

Despite these limitations, this electronic data is the only form of immunisation data that has the potential to be used as an intrinsic measure of immunisation delivery. How can this data best be used then? One potential solution to the data quality issues is to generate two estimates of coverage, one that assumes that all immunisation dates listed are correct and the other that excludes data that is of dubious quality.

An example of the first of these assumptions is to state that if the third in a series of vaccine doses is recorded on the PMS, then it is assumed that the previous two doses had been received, whether or not these were recorded. This is known as the 'third dose assumption' [23]. A study of the validity of this assumption in the Australian setting found that accepting the third dose assumption over-estimated coverage by only 0.2%, whereas if the assumption was not used, coverage was under-estimated by 7% [24].

An example of an assumption that is more dependent on data quality is one that requires the date for each immunisation and the date sequence for subsequent doses to both be valid—that is, an immunisation is assumed to have been given if an appropriate date is listed (a date after an earlier dose and before a subsequent dose).

The true coverage is then assumed to be between these upper and lower estimates. In addition to increasing confidence that immunisation coverage is not being over or under-estimated, the variance between these two coverage estimates can also be used as a measure of the quality of the practice immunisation data.

Detailed knowledge of current systems and processes was necessary to establish what seemed a straightforward outcome for this study of immunisation in primary health care. Such detailed scrutiny must be given to this data before it is incorporated in any regional or national immunisation register. The issues identified in this audit are likely to be present in any primary care system where electronic data is stored and reported. The developers of PMS must assume that any opportunity for human error will be made by someone and that reducing the potential for such error must be one of the main drivers for improving the quality of immunisation data and hence of immunisation delivery.

The entire electronic health record environment has developed in an ad hoc fashion. The complexity we encountered

in what we expected to be a relatively straightforward data collection reflects the lack of common models, systems of categorisation and integration of software design which would enable data interchange between different components of the health care system.

A major influence is the contextual nature of the medical information. Utilisation of health care data for secondary purposes such as research requires disentangling it from the context in which it was produced (in this case clinical encounters) and unless this was actively incorporated in the data collection design, this requires additional work [25]. Where the software is designed specifically for the task at hand, medical data sets can be effective research resources. For example, medical health care software designed to measure the numbers of children fully immunised in Bhorugram, an impoverished remote Indian community with high turn-over of primary health care providers, was able to successfully report an annual increase in immunisation uptake rates, and implementation of the computerised system is likely to have contributed to this improvement [26].

4.1. *Conclusion and recommendations*

On time delivery of scheduled immunisations is an important health outcome, included as one of the 13 health priority objectives in the NZ Health Strategy [27]. The data quality could be improved by defining a national minimum immunisation data set, and mandating its use by contracts with PHOs. Computerised PMS in primary care should enable accurate information about the receipt and timeliness of vaccinations given to our children. Obtaining this information would initially appear to be a straightforward task. However, our experience was that this is a complex and laborious task yielding poor quality data on some occasions.

To improve the situation, we recommend the following:

1. A standard very early age of registration and enrolment: ideally a child should be enrolled with a PHO at birth, but the 6 weeks check-up and first immunisation is also an opportune age.
2. A standard definition of the denominator: Automatic reports of immunisation coverage should include all the children under the care of a particular practice, to ensure an accurate denominator.
3. A standard definition of delay: Standard definitions need to be adopted for what is considered 'on time' or delayed vaccination. Where there are a series of vaccines, when the first vaccine has been delayed, the due date for the second or third dose dates should be readjusted accordingly and be considered 'on time' if this adjusted schedule is followed.
4. Greater uniformity and reduction in number of different PMS: In particular, the fields capturing immunisation data in PMS should be standardised.
5. Improved training for staff in the use of PMS systems.
6. Intrinsic data quality checks: As much as possible, recording of vaccine information should be menu-driven not free text, to increase the consistency of entered data. There should be only one place in the system where each piece of data can be entered, and dates need to match immunisation or decline events. There should be date range checks to prevent earlier dates entered for subsequent immunisations, the same date given for a series or an inappropriate date recorded for a specific vaccine such as MMR.
7. Changes in the immunisation schedule should result in subsequent updates of all PMS systems in use.
8. An incentive to improve the quality of the data.
9. Interval electronic checks on data quality conducted by the Ministry of Health as part of their data uploads.
10. Standardisation in use of international terminology: For example, Standard Nomenclature of Medicine (SNOMED) clinical terms. This of course also applies to issues other than immunisation.

Summary points

What was known before the study?

- Despite a free national immunisation schedule, less than 80% of New Zealand children are fully vaccinated by age 2 years.
- To date in New Zealand there has been a lack of any intrinsic mechanisms for measuring coverage.
- Recent changes to primary care in New Zealand include patient population capitation, electronic immunisation recording and national reporting by general practices.

What the study has added to the body of knowledge?

- Immunisation events electronically recorded at general practice level provide poor quality data for measuring immunisation receipt and timeliness.
- Practice management systems are not designed to generate aggregate data for regional/national/public health monitoring/surveillance and planning.
- Standardisation is required with respect to registration of children with practices, definition of immunisation denominator and delay, electronic entry of immunisation data, and data quality checks.

The accuracy of any future national immunisation register will only be as accurate as the data recorded at practice level. Even with these improvements, the system will still be imperfect—hence the need for the two alternative measures of immunisation which provide more (correct dose and date assumption) and less conservative (third dose assumption) estimates of immunisation coverage.

Electronic PMS can be excellent audit tools, but the axiom 'rubbish in, rubbish out' applies. Improving the quality of recorded data enables us to gain greater understanding of the pattern of immunisation coverage of our children. Consistency of the model used by practices would assist—for example defining when a immunisation becomes 'delayed' and when recall should be conducted; a common definition of the population of children for whom a practice is responsible

and a clear pathway as to the nature and mechanism of immunisation data transfer from practice to practice. PMS can be used for quality assurance and continuous quality improvement but do not easily generate aggregate data for regional, national, and public health monitoring, surveillance and planning.

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