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Reporting of gestational diabetes and other maternal medical conditions: validation of routinely collected hospital data from New South Wales, Australia

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Abstract

Introduction
Hospital datasets are a valuable resource for examining prevalence and outcomes of medical conditions during pregnancy. To enable effective research and health planning, it is important to determine whether variables are reliably captured.

Objective
To examine the reliability of reporting of gestational and pre-existing diabetes, hypertension, thyroid conditions, and morbid obesity in coded hospital records that inform the population-level New South Wales Admitted Patient Data Collection.

Methods
Coded hospital admission data from two large tertiary hospitals in New South Wales, from 2011 to 2015, were compared with obstetric data, collected by midwives at outpatient pregnancy booking and in hospital after birth, as the reference standard. Records were deterministically linked and sensitivity, specificity, positive predictive values and negative predictive values for the conditions of interest were obtained.

Results
There were 36,051 births included in the analysis. Sensitivity was high for gestational diabetes (83.6%, 95% CI 82.4–84.7%), pre-existing diabetes (88.2%, 95% CI 84.1–91.6%), and gestational hypertension (80.1%, 95% CI 78.2–81.9%), moderate for chronic hypertension (53.5%, 95% CI 47.8–59.1%), and low for thyroid conditions (12.9%, 95% CI 11.7–14.2%) and morbid obesity (9.8%, 95% CI 7.6–12.4%). Specificity was high for all conditions ($\geq$97.8%, 95% CI 97.7–98.0) and positive predictive value ranged from 53.2% for chronic hypertension (95% CI 47.5–58.8%) to 92.7% for gestational diabetes (95% CI 91.8–93.5%).

Conclusion
Our findings suggest that coded hospital data are a reliable source of information for gestational and pre-existing diabetes and gestational hypertension. Chronic hypertension is less consistently reported, which may be remedied by grouping hypertension types. Data on thyroid conditions and morbid obesity should be used with caution, and if possible, other sources of data for those conditions should be sought.

Keywords
gestational diabetes; hypertension; thyroid; pregnancy; hospital data; reliability; sensitivity

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Introduction

Timely, high quality, clinically relevant obstetric research is important to improve patient care for women and their newborns, so that as often as possible new mothers leave hospital healthy and with a healthy newborn. Hospital admission data are an efficient and rich resource for conducting such research on conditions that affect pregnancy and its outcomes [1–4]. Hospital data are also vital to inform decisions about health planning and, in many places, hospital funding [5]. Obstetric data do not always capture the range of procedures and conditions that can affect pregnant women and their babies, or may capture them in a way that is more difficult to analyse, such as free text. In addition, population level obstetric data are less commonly available than hospital data. Hospital data are usually coded with diagnosis and procedure codes following international coding standards, and therefore provide a useful alternative or supplement to obstetric data for obstetric research [1–4, 6]. In order to perform effective population-based research, however, researchers need information on the extent to which the data accurately reflect the clinical situation.

Reporting accuracy of diagnoses and procedures in hospital data may be affected by changes in practice and as different conditions become the focus of guidelines, management and audits. In the case of gestational diabetes, for example, changes in thresholds for diagnosis following the publication of results of a large prospective blinded observational study [7] have resulted in rates more than doubling in New South Wales (NSW), from 5.7% in 2005 to 12.2% in 2014, and gestational diabetes now accounts for almost 30% of planned births before 39 weeks gestation (unpublished data). Hospital data, collected when a woman is admitted to a maternity facility (hospital or birth centre) during pregnancy and birth, are a valuable resource for examining such changes over time and their impacts on outcomes, however they are typically collected for administrative purposes such as billing, rather than for research. Validation is therefore important to assess the reliability of hospital data sources.

This study examines reporting of maternal medical conditions including diabetes, hypertension, thyroid conditions and morbid obesity (BMI$>$40kg/m^2), which are associated with increased risks of adverse outcomes for mothers and babies [8–11], in hospital data. The most recent validation study assessing reporting of diabetes in coded NSW hospital data showed moderate reliability for gestational and high reliability for pre-existing diabetes, however it assessed data from 2002 [12], and predates the changes in diagnostic criteria. Previous studies have shown variable sensitivity for chronic hypertension (ranging from 44%–86%) [13, 14], gestational hypertension (10–71%) [15], thyroid conditions (10–97%) [15] and a systematic review [15] found only a single validation study for morbid obesity in hospital data, which showed low sensitivity (10%) [16]. Further, clinical practice and the obstetric population may have changed in the intervening years.

Validation studies may be conducted comparing coded hospital data with medical charts, however this process is time consuming and expensive to conduct, and tends to reflect only a short time period. An alternative approach is to compare reporting in two independent databases [17–19]. Here we compare reporting in coded hospital data, taken from the hospital records of birth and any pregnancy admissions, to obstetric data, collected from antenatal clinics and the obstetric record of the pregnancy and birth, using obstetric data as the reference standard.

The coded hospital data are drawn from the electronic medical record for a hospital admission, extracted by trained clinical coders following the International Classification of Diseases (ICD). A primary purpose of the coded diagnoses is to enable activity based funding (whereby hospitals are provided government funding largely on the basis of the treatment of patients), healthcare management and planning. The Australian Coding Standards provides guidelines to ensure consistency in clinical coding nationally. These limit conditions coded to those affecting patient management in the current admission, meaning that some chronic or other present conditions that do not affect the admission are not recoded. The guidelines also require coding to be substantiated by clear medical record documentation or confirmation from a clinician, and prohibit interpretation of results; for example, a recorded BMI of 40.1 kg/m^2 may not be assigned a code for obesity without an explicit, documented diagnosis of obesity in the notes [20, 21]. Coded data also inform various healthcare management and planning purposes, including the population-level New South Wales Admitted Patient Data Collection.

Obstetrics data were drawn from ObstetriX, a clinical database administered during pregnancy, birth and the early postnatal period, collected by midwives and partially self-reported. ObstetriX data inform the population-level New South Wales Perinatal Data Collection. ObstetriX may be considered an imperfect reference standard due to the different purposes and perspectives of the databases, however most reference standards are not without error and uncertainty [22, 23], and large population-level datasets have been demonstrated to be robust to random errors and omissions [24].

Methods

Study population

Women who gave birth to singleton infants in two tertiary hospitals in the Sydney metropolitan area between 1 January 2011 and 31 December 2015 formed the study population. All births in a hospital or birth centre, which in NSW are publicly funded facilities associated with public hospitals, are considered inpatient admissions and are assigned both an electronic medical record and obstetric record (in ObstetriX or a similar database such as eMaternity). In NSW, 99% of women birth in a hospital or birth centre [25]. Women who had prearranged to give birth in a different hospital to the actual hospital of birth were excluded, because antenatal data would have been collected at their hospital of booking rather than the hospital of birth, and therefore ObstetriX records may be incomplete for these women. Births of $\geq$28 weeks gestation were included for diabetes, as the screening test for gestational diabetes is recommended to be completed by 28 weeks, and $\geq$24 weeks gestation for other conditions.

Data sources

Obstetric data were obtained from the ObstetriX system (Meridian Health Informatics, Sydney, Australia), and linked to hospital data for admissions during pregnancy and the birth admission, drawn from the electronic medical record.

ObstetriX contains maternal health and demographic data, obstetric history and pregnancy details primarily obtained initially at the face-to-face booking consultation with a midwife (an outpatient encounter, by 16 weeks gestation). It is updated with labour, birth and postnatal information obtained during the birth admission, which is recorded and entered into the system contemporaneously. Data are recorded in checkboxes or drop-down menus, with a small number of free text fields. The data are entered by midwives, who do not have access to the hospital codes, as coding is performed four to six weeks after discharge. Most procedures and conditions are recorded as present, absent or unknown/missing. Presence or absence of the conditions of interest were obtained from checkbox or dropdown variables for the conditions, with the exception of morbid obesity, which was defined as having a body mass index (BMI) of 40.0 kg/m^2 or above in ObstetriX. A subset of ObstetriX data is submitted electronically to form the state-wide New South Wales Perinatal Data Collection.

The electronic medical record contains a record of diagnoses coded according to the International Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM), with a small number coded using Systematized Nomenclature of Medicine – Clinical Terms (SNOMED CT) codes. Procedures are coded following the Australian Classification of Health Interventions, Eighth Edition (ACHI). Coding is performed by medical coders based on clinical documentation in the electronic medical record. Although coders have access to ObstetriX data collected at birth, this information is not always coded unless the diagnoses and procedures are clearly present in the electronic medical record. Medical record diagnosis and procedure codes for admissions throughout pregnancy and the birth admission were searched for the relevant conditions. Where no record of the condition was found in any admission, the condition was deemed to be 'absent' for the purpose of this study. The diagnosis and procedure codes used in this study are provided in Supplementary Table 1. In order to maximise sensitivity for morbid obesity, parent codes for obesity and overweight (E66) and localised adiposity (E65) were used. The coded hospital data are submitted electronically from each hospital to form the New South Wales Admitted Patient Data Collection.

Records from the two sources were deterministically linked using patient Medical Record Number and checked using other personal identifiers, by personnel external to the project. Data were de-identified for analysis.

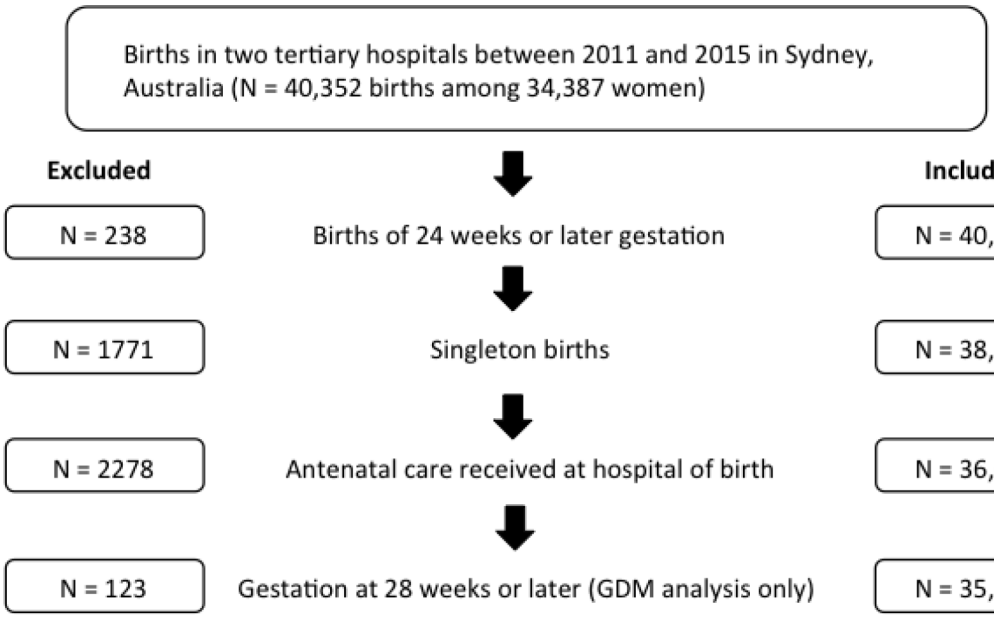
Validation methods

Reporting of gestational diabetes and other chronic disorders in the hospital data was compared to that in ObstetriX, using ObstetriX as the reference standard. Conditions recorded in any pregnancy admission or the birth admission in the coded hospital data were compared to conditions recorded in ObstetriX at any time for that pregnancy and birth. Records with missing data were excluded from the analysis of that variable. Sensitivity, specificity, positive and negative predictive values are reported with exact confidence intervals. Sensitivity and specificity were also calculated separately for the two hospitals. Analyses were performed in SAS 9.3. This study received ethics approval from the Northern Sydney Local Health District Human Research Ethics Committee (LNR/17/HAWKE32).

Results

There were 38,343 singleton infants born at 24 weeks gestation and older at the two hospitals between January 2011 and December 2015 (Figure 1). Of these, 36,051 received antenatal care at their birth hospital and were included in the analysis.

Figure 1: Flow diagram with study inclusion criteria



GDM = gestational diabetes.

Table 1: Reporting consistency between ICD10-coded hospital and ObstetriX datasets across two tertiary hospitals in New South Wales, 2011–2015, with ObstetriX as the reference standard

Condition	ObstetriX	Coded hospital data	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV % (95% CI)	NPV % (95% CI)
Gestational diabetes	4055	3654	83.6 (82.4–84.7)	99.2 (99.0–99.3)	92.7 (91.8–93.5)	97.9 (97.8–98.1)
Pre-existing diabetes	306	314	88.2 (84.1–91.6)	99.9 (99.8–99.9)	86.0 (81.6–89.6)	99.9 (99.9–99.9)
Any diabetes	4361	3953	84.8 (83.7–85.9)	99.2 (99.1–99.3)	93.6 (92.8–94.3)	97.9 (97.8–98.1)
Morbid obesity (BMI>40kg/m^2)	622	93	9.8 (7.6–12.4)	99.9 (99.9–99.9)	65.6 (55.0–75.1)	98.4 (98.3–98.5)
Thyroid conditions	2895	453	12.9 (11.7–14.2)	99.8 (99.7–99.8)	82.3 (78.5–85.7)	92.9 (92.6–93.2)
Chronic hypertension	314	316	53.5 (47.8–59.1)	99.6 (99.5–99.6)	53.2 (47.5–58.8)	99.6 (99.5–99.7)
Pre-eclampsia and eclampsia	610	817	80.0 (76.6–83.1)	99.1 (99.0–99.2)	59.7 (56.3–63.1)	99.7 (99.6–99.7)
Gestational hypertension[1]	1778	2170	80.1 (78.2–81.9)	97.8 (97.7–98.0)	65.6 (63.6–67.6)	99.0 (98.8–99.1)
Any hypertension	2035	2357	81.5 (79.8–83.2)	97.9 (97.8–98.1)	70.4 (68.5–72.2)	98.9 (98.8–99.0)

[1]including pre-eclampsia and eclampsia.

There were 35,928 infants born at 28 weeks and older and included in the analysis of gestational and pre-existing diabetes.

Sensitivity, specificity, positive and negative predictive values for the conditions of interest are provided in Table 1. Gestational diabetes was reliably reported over the period (sensitivity 83.6%, specificity 99.2%, PPV 92.7%), as was pre-existing diabetes (sensitivity 88.2%, specificity 99.9%, PPV 86.0%). Pre-eclampsia and eclampsia, gestational hypertension and any hypertension had good sensitivity (80.0%, 80.1%, 81.5%, respectively), but positive predictive value was moderate, showing that 30-40% of cases reported in the hospital data were not reported in ObstetriX (PPV 59.7%, 65.6%, 70.4%, respectively), and sensitivity and PPV for chronic hypertension were lower (sensitivity 53.5%, PPV 53.2%). Reporting of morbid obesity and thyroid conditions showed very low sensitivity (9.8%, 12.9% respectively), with moderate to high PPV (65.6% and 82.3%, respectively). Sensitivity increased for gestational diabetes, from 60.5% in 2011 to 95.7% in 2015 (Figure 2, Table 2), and increased less dramatically for pre-existing and any diabetes, gestational hypertension and any hypertension. Specificity and NPV were very high for all conditions examined.

Sensitivity and specificity were similar between the two hospitals (Supplementary Table 2). Specificity was very high for both hospitals. Sensitivity was slightly higher at Hospital One for non-diabetes related conditions, and there was less variation in sensitivity between hospitals for any hypertension compared to specific types of hypertension.

Consistency of reporting by characteristics of the pregnancy is provided in Table 2. For all conditions examined in detail, sensitivity was higher when a woman was nulliparous and where there was a hospital medical model of care (exclusive and with shared GP care), with the exception of gestational hypertension where midwife care had slightly higher sensitivity. Sensitivity to gestational diabetes was higher where the condition was managed with insulin or oral therapy compared to diet. Sensitivity increased by year for all conditions, most dramatically for gestational diabetes. Positive predictive value increased with time for pre-existing diabetes, but remained fairly stable for most other conditions, and decreased for hypertension. The median BMI of all those with a diagnosis in the hospital data of overweight, obesity or localised adiposity was 41.9 kg/m^2 (IQR 37.9–46.9 kg/m^2, $n = 93$).

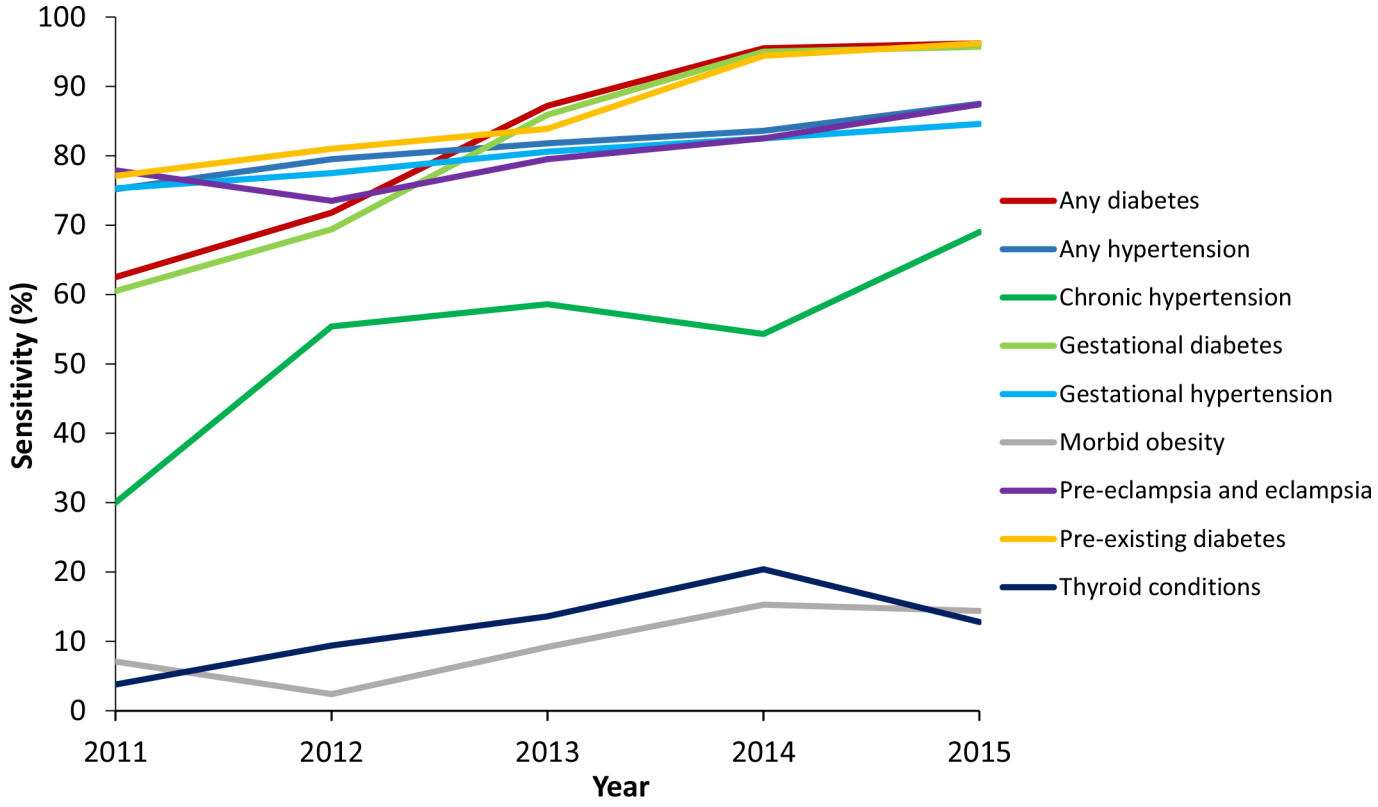
The hospital data appeared to contain some misclassification of pre-existing conditions as conditions that arose in pregnancy (Table 2). Among cases of gestational diabetes that were recorded in ObstetriX but uncoded in the hospital data (667 of 4055, 16.4%), 12 (1.8%) were recorded as having pre-existing diabetes, while among cases of pre-existing diabetes that were recorded in ObstetriX but uncoded in the hospital data (36 of 306, 5.2%), 19 (52.8%) were recorded as having gestational diabetes (6% of total cases). Similarly, of the gestational hypertension cases uncoded in the hospital data (354 of 1778, 19.9%), 44 (12.4%) were reported with chronic hypertension, while 79 (54.1%) of chronic hypertension cases uncoded in the hospital data (146 of 314, 46.5%, or 25% of total cases identified in ObstetriX) were reported instead to have gestational hypertension.

Rates of the conditions investigated at the two tertiary hospitals were generally within what would be expected for the population (Table 3). However morbid obesity was lower than expected, while gestational hypertension and thyroid conditions were higher than expected for the population.

Discussion

This study examined the reliability of coded hospital data for reporting of gestational diabetes and other maternal conditions, compared with ObstetriX data as the reference standard. Diabetes was well reported in the hospital data overall, with an increase over the time period from moderate to very high accuracy. Gestational hypertension, pre-eclampsia

Figure 2: Sensitivity for maternal conditions reported in coded hospital data from two tertiary hospitals in New South Wales, by year, compared to ObstetriX data as the reference standard



and eclampsia were moderately well reported, with high sensitivity but moderate PPV, while chronic hypertension had only moderate sensitivity and PPV. Using a broad 'any hypertension' category increased sensitivity and PPV and should be considered for studies using these data. Thyroid conditions and morbid obesity were poorly reported, with very low sensitivity and morbid obesity also showing moderate 'false' positives among cases that were reported, suggesting caution in the use of these data. Other sources of data on those two conditions should be sought where possible.

Sensitivity observed for pre-existing diabetes and gestational diabetes at the start of the study period were similar to that reported elsewhere [12, 21]. Sensitivity for chronic hypertension was within the range [13, 14] or slightly higher than reported elsewhere [21], while for gestational hypertension it was higher than previously observed [15, 21]. High sensitivity and low PPV for pre-eclampsia was also consistent with previous work [13, 26]. For thyroid conditions, sensitivity was at the lower limit of the range previously reported [15] and for morbid obesity sensitivity was consistent with poor ascertainment reported elsewhere [16]. The high specificity observed for all conditions was consistent with previous studies [12–16]. The higher sensitivity for more severe diabetes (among women with Type 1 or Type 2 requiring insulin compared to those not requiring insulin for pre-existing diabetes, and receiving insulin or oral therapy compared to those who did not for gestational diabetes), is consistent with previous research on diabetes [12] and findings that greater severity of a condition is associated with better reporting [17, 27].

Sensitivity increased over time for all conditions, although this was particularly stark for gestational diabetes and chronic hypertension. The general trend of increasing sensitivity over time may be partly related to the introduction of activity based funding, a government scheme for calculating hospital funding, which was ratified in 2011 and introduced in NSW in 2012. A systematic review of accuracy in UK hospital data found that a similar funding method, known as 'results based funding', was also associated with an increase in coding accuracy [28]. Sensitivity for gestational diabetes increased dramatically from 61% in 2011 to 96% in 2015, which is likely related to the change in diagnostic criteria and corresponding increased incidence and clinical focus on the condition and its management. This may have had flow on effects for pre-existing diabetes, for which the trend mirrored gestational diabetes.

Inconsistent reporting of thyroid conditions and morbid obesity are a reflection of the difficulties in capturing pre-existing, non-acute conditions from coded hospital data. Government policy and coding standards generally allow only conditions that affect the current admission to be coded, with the exception of diabetes and some other specific conditions. If a thyroid condition is well controlled, it requires negligible hospital resources during admission and is therefore unlikely to be recorded, although it may be recorded in the neonatal record since it can be more likely to impact the infant than mother. Morbid obesity may not be perceived as relevant to most hospital admissions during pregnancy, or staff may be reluctant to label a woman as obese due to negative connotations. The different timing of data collection between the two datasets may also play a role; for example, a person

Table 2: Reliability of reporting of gestational diabetes and hypertension in coded hospital data from two tertiary hospitals in New South Wales, 2011–2015, by characteristics of pregnancy

Condition	Characteristic	Value	ObstetriX	Hospital data	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV % (95% CI)	NPV % (95% CI)
Gestational diabetes	Parity	Nulliparous	1893	1749	86.9 (85.3–88.4)	99.3 (99.1–99.4)	94.1 (92.8–95.1)	98.3 (98.1–98.5)
		Parous	2147	1889	80.5 (78.7–82.1)	99.0 (98.9–99.2)	91.5 (90.1–92.7)	97.5 (97.3–97.8)
	Year of birth	2011	653	422	60.5 (56.6–64.3)	99.6 (99.4–99.7)	93.6 (90.8–95.7)	96.0 (95.5–96.5)
		2012	690	522	69.4 (65.8–72.8)	99.3 (99.1–99.5)	91.8 (89.1–94.0)	96.8 (96.3–97.2)
		2013	764	714	85.9 (83.2–88.3)	99.1 (98.8–99.3)	91.9 (89.6–93.8)	98.3 (97.9–98.6)
		2014	918	941	95.0 (93.4–96.3)	99.0 (98.7–99.2)	92.7 (90.8–94.3)	99.3 (99.1–99.5)
		2015	1030	1055	95.7 (94.3–96.9)	98.9 (98.6–99.1)	93.5 (91.8–94.9)	99.3 (99.1–99.5)
	Model of care	Hospital medical	2709	2454	85.0 (83.7–86.4)	98.6 (98.4–98.9)	93.9 (92.9–94.8)	96.4 (96.1–96.8)
		Midwife	1020	914	80.7 (78.1–83.1)	99.5 (99.4–99.6)	90.0 (87.9–91.9)	98.9 (98.7–99.0)
		Private OB or GP	326	285	80.1 (75.3–84.3)	99.1 (98.7–99.5)	91.6 (87.7–94.5)	97.7 (97.1–98.2)
	Management[2]	Diet	2170	1690	77.9 (76.1–79.6)	–	–	–
		Insulin/oral	1885	1698	90.1 (88.6–91.4)	–	–	–
Pre-existing diabetes	Parity	Nulliparous	117	126	91.5 (84.8–95.8)	99.9 (99.8–99.9)	84.9 (77.5–90.7)	99.9 (99.9, 100.0)
		Parous	188	187	86.2 (80.4–90.8)	99.9 (99.8–99.9)	86.6 (80.9–91.2)	99.9 (99.8–99.9)
	Year of birth	2011	35	34	77.1 (59.9–89.6)	99.9 (99.8–100.0)	79.4 (62.1–91.3)	99.9 (99.8–99.9)
		2012	58	56	81.0 (68.6–90.1)	99.9 (99.8–99.9)	83.9 (71.7–92.4)	99.8 (99.7–99.9)
		2013	62	63	83.9 (72.3–92.0)	99.8 (99.7–99.9)	82.5 (70.9–90.9)	99.9 (99.7–99.9)
		2014	72	76	94.4 (86.4–98.5)	99.9 (99.8–100.0)	89.5 (80.3–95.3)	99.9 (99.9–100.0)
		2015	79	85	96.2 (89.3–99.2)	99.9 (99.8–99.9)	89.4 (80.8–95.0)	100.0 (99.9–100.0)
	Model of care	Hospital medical	261	266	89.7 (85.3–93.1)	99.8 (99.7–99.8)	88.0 (83.4–91.6)	99.8 (99.7–99.9)
		Midwife	11	13	54.5 (23.4–83.3)	100.0 (99.9–100.0)	46.2 (19.2–74.9)	100.0 (99.9–100.0)
		Private OB or GP	34	35	88.2 (72.5–96.7)	99.8 (99.6–99.9)	85.7 (69.7–95.2)	99.9 (99.7–100.0)
	Management[2]	Type 1 insulin	141	130	92.2 (86.5–96.0)	–	–	–
		Type 2 insulin	94	85	90.4 (82.6–95.5)	–	–	–
		Type 2 no insulin	71	55	77.5 (66.0–86.5)	–	–	–
Any diabetes	Parity	Nulliparous	2010	1872	88.0 (86.5–89.4)	99.3 (99.1–99.4)	94.4 (93.3–95.4)	98.4 (98.2–98.6)
		Parous	2335	2064	82.0 (80.4–83.6)	99.1 (98.9–99.2)	92.8 (91.6–93.9)	97.5 (97.3–97.7)
	Year of birth	2011	688	458	62.5 (58.8–66.1)	99.5 (99.3–99.7)	93.9 (91.3–95.9)	96.0 (95.4–96.4)
		2012	748	576	71.8 (68.4–75.0)	99.4 (99.2–99.6)	93.2 (90.9–95.1)	96.7 (96.3–97.2)
		2013	826	775	87.2 (84.7–89.4)	99.1 (98.8–99.3)	92.9 (90.9–94.6)	98.3 (97.9–98.6)
		2014	990	1009	95.5 (94.0–96.7)	99.0 (98.7–99.2)	93.7 (92.0–95.1)	99.3 (99.1–99.5)
		2015	1109	1135	96.2 (94.9–97.3)	98.9 (98.6–99.2)	94.0 (92.5–95.3)	99.3 (99.1–99.5)
	Model of care	Hospital medical	2970	2705	86.5 (85.3–87.7)	98.8 (98.5–99.0)	95.0 (94.1–95.8)	96.4 (96.0–96.7)
		Midwife	1031	926	81.0 (78.5–83.3)	99.5 (99.4–99.6)	90.2 (88.1–92.0)	98.9 (98.7–99.0)
		Private OB or GP	360	321	81.7 (77.3–85.5)	99.0 (98.6–99.4)	91.6 (88.0–94.4)	97.7 (97.0–98.2)
Any hypertension	Parity	Nulliparous	1139	1372	86.6 (84.4–88.5)	97.5 (97.3–97.8)	71.9 (69.4–74.2)	99.0 (98.8–99.2)
		Parous	889	978	75.1 (72.2–78.0)	98.3 (98.1–98.5)	68.3 (65.3–71.2)	98.8 (98.6–98.9)
	Year of birth	2011	420	414	75.2 (70.8–79.3)	98.5 (98.2–98.8)	76.3 (71.9–80.3)	98.4 (98.1–98.7)
		2012	395	448	79.5 (75.2–83.4)	98.0 (97.6–98.3)	70.1 (65.6–74.3)	98.8 (98.5–99.0)
		2013	384	440	81.8 (77.5–85.5)	98.1 (97.8–98.4)	71.4 (66.9–75.5)	98.9 (98.7–99.2)
		2014	427	536	83.6 (79.7–87.0)	97.5 (97.1–97.8)	66.6 (62.4–70.6)	99.0 (98.7–99.2)
		2015	409	519	87.5 (83.9–90.6)	97.7 (97.3–98.0)	69.0 (64.8–72.9)	99.3 (99.0–99.4)
	Model of care	Hospital medical	1310	1424	82.9 (80.8–84.9)	97.3 (97.0–97.6)	76.3 (74.0–78.5)	98.2 (98.0–98.4)
		Midwife	468	681	81.0 (77.1–84.4)	98.4 (98.2–98.5)	55.7 (51.8–59.4)	99.5 (99.4–99.6)
		OB or GP	232	246	81.5 (75.9–86.2)	98.1 (97.5–98.5)	76.8 (71.0–82.0)	98.5 (98.0–98.9)
Gestational hypertension[1]	Parity	Nulliparous	1041	1284	85.5 (83.2–87.6)	97.5 (97.3–97.7)	69.3 (66.7–71.8)	99.0 (98.9–99.2)
		Parous	731	879	72.4 (69.0–75.6)	98.1 (97.9–98.3)	60.2 (56.9–63.4)	98.9 (98.7–99.0)
	Year of birth	2011	364	384	75.3 (70.5–79.6)	98.3 (98.0–98.6)	71.4 (66.5–75.8)	98.6 (98.3–98.9)
		2012	356	409	77.5 (72.8–81.8)	98.0 (97.7–98.3)	67.5 (62.7–72.0)	98.8 (98.5–99.1)
		2013	324	404	80.6 (75.8–84.7)	97.9 (97.5–98.2)	64.6 (59.7–69.3)	99.1 (98.8–99.3)
		2014	371	492	82.5 (78.2–86.2)	97.4 (97.0–97.8)	62.2 (57.7–66.5)	99.1 (98.8–99.3)
		2015	363	481	84.6 (80.4–88.1)	97.5 (97.1–97.9)	63.8 (59.4–68.1)	99.2 (99.0–99.4)
	Model of care	Hospital medical	1106	1277	80.8 (78.4–83.1)	97.0 (96.7–97.3)	70.0 (67.4–72.5)	98.3 (98.1–98.5)
		Midwife	451	662	81.4 (77.5–84.9)	98.4 (98.2–98.6)	55.4 (51.6–59.3)	99.5 (99.4–99.6)
		Private OB or GP	196	225	80.6 (74.4–85.9)	97.8 (97.2–98.3)	70.2 (63.8–76.1)	98.7 (98.2–99.1)

OB = obstetrician, GP = General Practitioner.
[1]including pre-eclampsia and eclampsia.
[2]recorded in ObstetriX.

may report a history of thyroid disorder that is recorded in ObstetriX but has resolved or no longer requires medication, and therefore is uncoded in the hospital data.

We found evidence of misclassification of pre-existing conditions as conditions arising in pregnancy, with a tendency for chronic hypertension and pre-existing diabetes to be

Table 3: Rates of diagnoses across two hospitals in New South Wales, 2011–2015, reported in ObstetriX and coded hospital data, compared to estimated population prevalence based on other studies

Variable	ObstetriX n (%)	Hospital data n (%)	Either n (%)	Population prevalence in other studies %
Gestational diabetes	4055 (11.4)	3654 (10.2)	4335 (12.1)	6.5–13.8[2]
Pre-existing diabetes	306 (0.9)	314 (0.9)	351 (1.0)	1.0–1.0[3]
Any diabetes	4361 (12.2)	3953 (11.0)	4629 (12.9)	7.0–9.8[4]
Morbid obesity (BMI >40 kg/m^2)	622 (1.8)	93 (0.3)	654 (1.8)	3.0–3.0[5]
Thyroid conditions	2895 (8.0)	453 (1.3)	2975 (8.3)	2.0–3.0[6]
Chronic hypertension	314 (0.9)	316 (0.9)	462 (1.3)	0.8–0.8[4]
Pre-eclampsia and eclampsia	610 (1.7)	817 (2.3)	939 (2.6)	1.5–1.7[4]
Gestational hypertension[1]	1778 (4.9)	2170 (6.0)	2524 (7.0)	2.8–3.1[4]
Any hypertension	2035 (5.6)	2357 (6.5)	2733 (7.6)	5.1–5.6[4]

[1]including pre-eclampsia and eclampsia.
[2]age-standardised incidence of gestational diabetes in Australia, 2010–11 to 2015–16 [31].
[3]rates of pre-existing diabetes in pregnancy in Australia, 2011–2015 in Australian birth data [32].
[4]rates of any diabetes among women giving birth in NSW, range for 2011–2015, from NSW birth data [35].
[5]rates of morbid obesity (BMI $\geq$ 40.0 kg/m^2) in Australian birth data (excluding NSW), 2011–2015 [33, 34].
[6]rate of thyroid dysfunction in pregnant women [30].

reported as gestational hypertension and diabetes, which has been previously observed [12]. This was more common for diabetes (25% of all cases) compared to hypertension (6% of all cases).

Rates reported in ObstetriX were similar to what would be expected for the population [29–34]. Slightly higher rates of gestational hypertension and thyroid conditions may reflect that the hospitals included are tertiary hospitals. Morbid obesity was lower than the expectation for the population, perhaps reflecting the fact that both hospitals are located in metropolitan Sydney, where morbid obesity rates tend to be slightly lower than rural and regional areas [35].

Consistency of reporting was similar for the two hospitals, suggesting that the results hold across different socioeconomic and ethnic patient populations, locations, and facilities. Slight differences in the rates may reflect the different demographic compositions, with Hospital One tending to have an older obstetric population with a different mix of ethnicities and comorbidities [36].

Limitations

ObstetriX is an imperfect reference standard, given the different purposes, perspectives and collection times of the two datasets. ObstetriX data are largely self-reported, which may be inaccurate or inconsistent [37], and the data are entered by busy clinical staff, with accuracy of data entry sometimes difficult to achieve when personnel are busy providing clinical care. Due to multiple caregivers, the person entering the data is generally not present for the entire episode of care.

Further, the fact that the data in ObstetriX are collected to a large extent by 16 weeks gestation (supplemented with data from the labour and birth), while hospital data are collected during the admission for the birth and any other admissions during pregnancy, may affect the quality of ObstetriX as a reference standard, as issues may arise or resolve between early pregnancy and birth. This may have resulted in under-enumeration of true cases in ObstetriX and underestimation of PPV. For example, a woman with chronic hypertension may be first diagnosed after the booking visit (since the definition of chronic hypertension in pregnancy is raised blood pressure before 20 weeks). In this case it will be missed at the booking visit due to being undiagnosed, and as a non-pregnancy-induced condition the likelihood that it would be recorded in ObstetriX at the time of birth is low. This is unlikely to be the case for other conditions, however, including gestational hypertension, as pregnancy-induced conditions would be recorded in the data collected at birth. Nevertheless, where linked data are available, drawing on both data sources to identify cases is probably the best approach, particularly where a condition may be expected to arise late in pregnancy.

Data were available from two hospitals only. However, the hospitals represent different ethnic and socioeconomic compositions, and the similarities of reporting between hospitals are encouraging.

Conclusion

Our findings suggest that coded hospital data are a reliable source of information for gestational diabetes, pre-existing diabetes and all types of hypertension, with the exception

of chronic hypertension. Chronic hypertension was reported moderately well, and reliability would be improved by using a grouped category for any hypertension. As thyroid conditions and morbid obesity were poorly reported, coded hospital data should be used with caution for these conditions and if possible, other sources of data should be sought. While there may be local idiosyncrasies in coding and reporting, NSW hospital data are coded following international coding standards, with ICD-10 widely used worldwide [15, 38], and previous studies have shown similar sensitivities between NSW hospital data and data from elsewhere [21]. We therefore consider these findings to be reasonably generalizable to other settings.

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Statement of conflicts of interest

None declared.

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Abbreviations

ICD: International Classification of Diseases
BMI: body mass index
PPV: positive predictive value
NPV: negative predictive value
OB: obstetrician
GP: General Practitioner

Supplementary Table 1: ICD-10-AM diagnostic and ACHI 8th Edition procedure codes used to ascertain presence of conditions in the coded hospital data

Condition	Diagnostic codes	Procedure codes
Gestational diabetes	O24.4	
Pre-existing diabetes	O24.0, E10, O24.1, E11, O24.2, O24.3, E13, E14	
Morbid obesity (BMI $>$ 40 kg/m^2)*	E65, E66	
Thyroid conditions	E00, E01, E02, E03, E04, E05, E06, E07, E89.0,O90.5	30075-03, 30094-10, 30296-00, 30296-01, 30297-00, 30297-01, 30297-02, 30306-00, 30306-01, 30308-00, 30309-00, 30310-00, 90041-00, 90046-00, 90046-01, 90047-00, 90047-01, 90046-02, 90047-02†
Chronic hypertension	I10, O10, O11	
Pre-eclampsia and eclampsia	O14, O15	
Gestational hypertension	O11, O13, O14, O15, O16	

*Obesity and localised adiposity.
†Where record is not the birth record.

Supplementary Table 2: Sensitivity and specificity of reporting in coded hospital data compared to ObstetriX data as the reference standard, from two tertiary hospitals in New South Wales, 2011–2015, by hospital

	Hospital one		Hospital two	
	Sensitivity	Specificity	Sensitivity	Specificity
Gestational diabetes	80.6 (78.4–82.6)	99.7 (99.6–99.8)	85.1 (83.7–86.4)	98.9 (98.8–99.0)
Pre-existing diabetes	93.0 (85.4–97.4)	99.9 (99.8–100.0)	86.4 (81.1–90.6)	99.9 (99.8–99.9)
Any diabetes	81.5 (79.4–83.5)	99.7 (99.6–99.8)	86.5 (85.2–87.7)	99.0 (98.8–99.1)
Morbid obesity (BMI $>$ 40 kg/m^2)	13.5 (8.5–20.1)	99.9 (99.8–99.9)	8.6 (6.3–11.6)	99.9 (99.9–100.0)
Thyroid conditions	15.7 (13.3–18.4)	99.7 (99.6–99.8)	11.8 (10.4–13.2)	99.8 (99.7–99.8)
Chronic hypertension	61.2 (50.0–71.6)	99.5 (99.4–99.6)	50.7 (44.0–57.3)	99.6 (99.5–99.7)
Pre-eclampsia and eclampsia	85.1 (79.3–89.8)	99.2 (99.0–99.4)	77.6 (73.3–81.5)	99.0 (98.9–99.1)
Gestational hypertension[1]	85.1 (81.7–88.0)	98.3 (98.0–98.5)	78.0 (75.6–80.3)	97.6 (97.4–97.8)
Any hypertension	85.8 (82.8–88.5)	98.4 (98.1–98.6)	85.1 (83.7–86.4)	98.9 (98.8–99.0)

[1]including pre-eclampsia and eclampsia.