INTRODUCTION

Delayed cord clamping (DCC) has been shown to be beneficial for infants, by increasing haemoglobin levels at birth and improving iron stores in the first several months of life.\(^1\) Especially in preterm infants, DCC is associated with improved transitional circulation, lower rates of necrotising enterocolitis, and intraventricular haemorrhage.\(^2,3\) DCC is defined as a delay of more than 30 seconds, but less than 180 seconds.\(^2\) As a major tertiary centre for preterm deliveries, the Mater Mothers’ Hospital has developed guidelines for implementing DCC in preterm births (PTB). Mater’s default practice is for DCC for births prior to 32 weeks (very preterm) unless otherwise contraindicated. DCC may also be beneficial for babies born between 32 and 37 weeks (moderate-to-late preterm) and should be considered and discussed with the expectant parents. Contraindications to DCC include poor neonatal condition at birth warranting immediate resuscitation, and maternal bleeding requiring prompt intervention.

An additional consideration for clinicians is the desire to obtain cord blood gas (CBG) sampling. CBG analysis provides information on fetal oxygenation and metabolic state around the time of birth, which has important management implications. Prompt neonatal assessment is indicated for significant blood gas derangements regarding severe acidosis. However, due to reduced blood within the vessels with DCC, delayed sampling may be difficult and lead to an increased number of failed samples for analysis. Since PTB is an indication for CBG analysis according to Mater guidelines, in a practical sense, the desire for DCC can be in conflict with a desire to obtain CBG sampling.

While there are studies investigating the effect of DCC on the accuracy of cord gases to reflect the fetal status,\(^4-6\) evidence regarding impact of DCC on actual success rates of CBG analysis is lacking and inconclusive. We reviewed the rates of DCC in our centre and whether the process of DCC affected the adequacy of CBG sampling for analysis.

MATERIALS AND METHODS

Study design and cohort

A retrospective cohort study was performed to assess the impact of DCC on CBG sampling and analysis since 2019 (when relevant preterm birth guidelines at our hospital were updated). Women
who delivered at the Mater Mothers’ Hospital between February 2019 and May 2021 were included. Exclusion criteria included births at pre-viable gestations (less than 23 weeks) and intrauterine fetal death/stillbirths (Figure S1).

**Definition of exposures and outcomes**

Data were extracted from Matrix database (Maternity Database for Mater Mothers’ Hospital), including maternal demographics (age, body mass index, smoking status, parity), gestational age at delivery (completed weeks), mode of delivery (spontaneous vaginal delivery (SVD), vacuum delivery, forceps delivery and caesarean section), timing of cord clamping (early or delayed), estimated blood loss, APGAR score at one minute, CBG sampling (attempted or not attempted) and outcome of CBG analysis. Assisted births included vacuum delivery, forceps delivery and caesarean sections.

Successful CBG analysis is defined as paired (both arterial and venous) cord gas sampled with valid analysis. Rate of successful CBG analysis was determined using only cases with documented CBG sampling attempts as denominator to eliminate non-compliance to guideline as a confounding factor.

Sub-analysis was performed in the preterm cohort to determine variation in compliance to policy depending on types of accoucheur and mode of delivery.

**Statistical analysis**

Statistical analysis was performed using Jamovi software. $\chi^2$ test was used to assess significance in difference in proportions. For statistical analysis of continuous variables, independent $t$-test and Mann–Whitney $U$-test were used according to distribution.

This project was granted formal exemption from full ethical review by the Chairperson of the Mater Misericordiae Ltd Human Research Ethics Committee (reference number: EXMT/MML/75803 (V1)).

**RESULTS**

There were 24 383 births between February 2019 and May 2021, of which 21 953 were term and 2430 were preterm (Figure S1). The mean maternal age was 32 years. There was a significantly higher rate of smoking and nulliparity among the preterm cohort ($P < 0.001$; Table 1).

**Impact of timing of cord clamping on success rate of cord gas analysis**

Successful paired CBG analysis was significantly related to timing of cord clamping. There were 8.3% and 7.7% less successful paired CBG analyses following DCC in the term and preterm cohort respectively (Table 2).

**Timing of cord clamping**

There were 17.9% more episodes of DCC in the very preterm cohort compared to the moderate-to-late preterm group (62.9% vs 45.0%; $\chi^2 = 51.5, P < 0.001$).

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### TABLE 1 Demographic and peripartum characteristics of patients

| Variable                              | Entire dataset ($N = 24$ 383) | Preterm ($n = 2430$) | Term ($n = 21953$) | $P$-value |
|---------------------------------------|-------------------------------|-----------------------|---------------------|-----------|
| Maternal age, years†                  | 32.3 (5.01)                   | 32.3 (5.59)           | 32.3 (4.95)         | 0.967     |
| Ethnicity                             |                               |                       |                     |           |
| Caucasian                             | 14210 (59.4)                  | 1288 (61.8)           | 12922 (59.2)        | <0.001    |
| ATSI‡                                 | 649 (2.7)                     | 87 (4.2)              | 562 (2.6)           | <0.001    |
| South-east Asian                      | 5419 (22.7)                   | 396 (19.0)            | 5023 (23.0)         | <0.001    |
| Māori/Pacific Islander               | 811 (3.4)                     | 74 (3.5)              | 737 (3.4)           | 0.625     |
| Other                                 | 2833 (11.8)                   | 240 (11.5)            | 2593 (11.9)         | 0.624     |
| Smoker                                | 942 (3.9)                     | 143 (6.9)             | 799 (3.7)           | <0.001    |
| Body mass index, kg/m$^2$†            | 24.7 (5.88)                   | 25.1 (6.61)           | 24.7 (5.81)         | 0.005     |
| Nulliparity                           | 11074 (46.3)                  | 1014 (48.6)           | 10060 (46.1)        | <0.001    |
| Mode of delivery                      |                               |                       |                     |           |
| Spontaneous vaginal birth             | 11103 (45.5)                  | 722 (29.7)            | 10381 (47.3)        | <0.001    |
| Vacuum delivery                       | 2357 (9.7)                    | 63 (2.6)              | 2294 (10.4)         |           |
| Forceps delivery                      | 668 (2.7)                     | 62 (2.6)              | 606 (2.8)           |           |
| Caesarean section                     | 10244 (42.0)                  | 1580 (65.0)           | 8664 (39.5)         |           |
| Estimated blood loss >1 L             | 1309 (5.4)                    | 203 (8.4)             | 1106 (5.1)          | <0.001    |

Note. Data presented as $n$ (%), except where otherwise specified.

†Mean (SD).

‡ATSI, Aboriginal and Torres Strait Islander.
Cord gas sampling

There was a significant difference in rate of CBG sampling attempted depending on gestational age in the entire cohort and within the preterm cohort. There was 31.7% more CBG sampling attempted in the preterm cohort compared to the term cohort (66.6% vs 34.9%; \( \chi^2 = 929, P < 0.001 \)). Within the preterm cohort, the rate was 19.2% higher in the very PTB than the moderate-to-late PTB (81.6% vs 62.4%; \( \chi^2 = 67.7, P < 0.001 \)).

Preterm cohort sub-analysis

Subgroup analysis of the preterm cohort found that DCC was more frequently performed by midwifery accoucheur than doctors (64.7% vs 45.3%; \( \chi^2 = 52.0, P < 0.001 \)), as well as in SVD compared to assisted births (63.3% vs 42.9%; \( \chi^2 = 83.5, P < 0.001 \)).

There was no statistically significant difference in rate of CBG sampling attempted by midwifery accoucheur compared to doctors (65% vs 67.4%; \( P = 0.342 \)). The rate of CBG sampling was higher in assisted births compared to SVD (69.3% vs 60.4%; \( \chi^2 = 39.8, P < 0.001 \)).

Within the preterm cohort, the median APGAR score at one minute was significantly lower in births attended by doctors compared to midwives (eight vs nine; \( P < 0.001 \)), as well as in assisted births compared to SVD (eight vs nine; \( P < 0.001 \)).

DISCUSSION

We found rates of DCC among the very PTB to be 62.9% despite the process being routinely recommended. CBG sampling was performed in two-thirds of PTB (66.6%), and up to 81.6% in the very preterm cohort. We also demonstrated a consistent and significant decrease in ability to obtain successful CBG analysis in both the term and preterm cohort following DCC, highlighting the difficulty in achieving both recommendations.

While the apparent low DCC rate may be partially explained by the possible clinical contraindications, operator oversight likely contributes to a significant portion of non-compliance. This may be improved with targeted staff education and improvement initiatives.

Interestingly, we found that doctors have a lower rate of DCC in PTB compared to midwives (45.3% vs 64.7%). A possible explanation may be that doctors were involved in the setting of fetal distress when birth needed to be expedited and thus immediate cord clamping was performed to facilitate anticipated neonatal resuscitation. This postulation is substantiated by the findings of a statistically significant lower median APGAR score in births attended by doctors.

Similarly, the rate of DCC with assisted births was also lower than that of SVD (42.9% vs 63.3%). Since CBG analysis provides valuable information which may dictate management and prognosis, and thus are of particular importance in the presence of peripartum fetal distress, the rate of CBG sampling performed in the assisted birth group was significantly higher than in the SVD group (69.3% vs 60.4%). It may be that preference for obtaining CBG analysis superseded the clinician’s desire to perform DCC.

To our knowledge, this is the first study to illustrate the potential impact of DCC on success rate of CBG analysis in both term and PTB. Andersson et al in 2013 reported a 6% reduction in valid samples obtained after DCC in term gestation only, although this was not statistically significant.\(^7\) Rhoades et al in 2017 found no difference in the ability to obtain a single or paired umbilical CBG result following DCC in the very preterm cohort (<32 weeks); however, their overall rate of obtaining of paired cord gases was low.\(^8\) Rhoades et al in 2019 subsequently investigated the rates in the term cohort and found a statistically significant decrease in success rate of paired CBG sampling following DCC.\(^9\)

A limitation of this study is the use of retrospective data and reliance on accuracy of the clinical record. Furthermore, while we adjusted for a significant confounder (ie non-compliance to policy) when assessing the impact of DCC on success rates of CBG analysis, there may be potential residual confounding factors (ie potential delays between obtaining of sample to analysis, machinery failure etc). Also, we did not review the clinical relevance of unsuccessful CBG analysis on the management and outcome of the neonate. Follow-up studies should aim to explore cases where CBG analysis is most needed; however, this can be difficult as DCC is the primary objective and first event to occur following preterm birth, prior to the attempt at CBG sampling.

In conclusion, this study establishes that DCC is associated with a reduction in success rate of CBG analysis regardless of gestational age. This finding is an important consideration when performing DCC especially in the preterm cohort. Clinicians should be aware that obtaining successful CBG analysis may be less likely. Therefore, we recommend a multidisciplinary approach, with neonatal involvement, in decision making regarding DCC in PTB and the relative importance of CBG analysis in each individual case.

### TABLE 2  Successful cord gas analysis based on timing of cord clamping

|                  | Immediate cord clamping, n (%) | Delayed cord clamping, n (%) | Statistical analysis |
|------------------|--------------------------------|------------------------------|----------------------|
| Entire cohort    | 4935 (88.9)                    | 2971 (80.6)                  | \( \chi^2 = 122, P < 0.001 \) |
| Term             | 4199 (89.1)                    | 2370 (80.8)                  | \( \chi^2 = 103, P < 0.001 \) |
| Preterm          | 736 (87.5)                     | 601 (79.8)                   | \( \chi^2 = 17.4, P < 0.001 \) |
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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1