BACKGROUND: Maternal morbidity is becoming a key indicator used to compare health systems in the developed world and also to inform clinical practice.

OBJECTIVE: This study aimed to evaluate a single center experience of severe maternal morbidity over an 8-year period.

STUDY DESIGN: We conducted a retrospective review of all cases of severe maternal morbidity from 2012 to 2019 at a tertiary level maternity hospital in the Republic of Ireland with approximately 9000 births per year. We examined maternal demographics, pregnancy characteristics, and care requirements. Descriptive statistics were used throughout.

RESULTS: There were 81,504 maternity cases and 67,894 births during the study period. A total of 504 women had a severe maternal morbidity, giving a rate of 6.1 per 1000 maternity cases overall, peaking in 2017 at 8.8 per 1000. When individual severe maternal morbidity events were evaluated, the rate increased from 6 per 1000 to 9 per 1000 over the 8-year period. There were no differences in maternal age, nationality, or body mass index during the years analyzed. Interestingly, 8.9% (n=45) were multiple gestations, and nearly one-fifth (19.4%; n=98) required escalation of care to a general hospital; of these, 14.0% (n=74) required cardiac or intensive care management. The majority of morbidities manifested in the third trimester (58.7%; n=296) or postnatally (42.8%, n=216). The most common severe maternal morbidities were hypertensive disorders of pregnancy, followed by postpartum hemorrhage and sepsis (45.0%, 44.2%, and 12.7%, respectively).

CONCLUSION: We provide a longitudinal overview of severe maternal morbidity in a large maternity hospital that replicates other international findings. This information can be used for healthcare comparisons and for resource planning and allocation.

Key words: epidemiology, maternal morbidity, obstetrics

Introduction
The measurement of quality in healthcare is a ubiquitous concept and a focus for healthcare systems internationally. Researchers and clinicians focus on comparing healthcare systems and aim to create the safest, most efficient, and economic healthcare models that provide the best patient outcomes. The World Health Organization (WHO) have compiled a list of 100 Core Health Indicators to assist countries in the monitoring and evaluation of healthcare systems. The inclusion of reproductive health indicators show the importance that are placed on these parameters internationally.

Maternal and perinatal mortality are key outcome measures reported internationally and are an essential component of the United Nations Sustainable Development Goals. The goal for these key outcome measures is to reduce global maternal mortality to <70 per 100,000 live births and to reduce neonatal mortality to <12 per 1000 live births. Although most high-income countries have met this target, maternal morbidity has become a focus as a quality indicator.

The use of severe maternal morbidity (SMM) internationally as a key performance indicator and quality of care parameter is increasing. SMM has been described as the base of the iceberg, whereas maternal mortality is the tip of the iceberg, implying that investigating SMM holds benefits for healthcare providers and healthcare users. However, the spectrum that encompasses maternal morbidities is wide-ranging and can span from a maternal near miss to a non—life-threatening morbidity. Therefore, there are large discrepancies internationally in the classification and reporting of SMMs. For example, the International Classification of Diseases, 10th Revision, is used in some countries, such as the United States, with some discrepancies within countries on SMM reporting structures despite a recognition for consistent reporting to allow for comparisons. Given that institutional criteria are unlikely to deviate, it is feasible to measure SMM longitudinally, which can aid in structuring an approach to tackle the rising rate of SMM.

Therefore, we aimed to review the longitudinal institutional rate of SMM and to evaluate the demographic features of patients with an SMM in our population.

Material and Methods
In this descriptive study, we conducted a retrospective review of all cases with SMM over an 8-year period from
January 1, 2012 to December 31, 2019. The study was conducted at a tertiary level, stand-alone maternity hospital in the Republic of Ireland, with circa 9000 maternity cases per year. There are high dependency unit facilities (that can provide basic cardiovascular and neurologic support, but not basic respiratory support), with capacity to transfer patients to a nearby level 4 hospital.

All women who were deemed to have a pregnancy complicated by an SMM were included in a customized database and were added to the database on diagnosis of their SMM. The database was initially started to capture data from an institutional perspective and was then used to report data nationally on an annual basis. Given the change in function of this database as the need evolved, there was the addition of some variables in later years of data collection. As such, SMM event rate refers to singular events of SMM, which may occur in the same individual, whereas reportable SMM figures refer to individuals who may experience multiple SMM events.

In total, 48 variables were collected in the following categories: (1) maternal demographics (eg, age, nationality, body mass index), (2) pregnancy characteristics (eg, parity, gestational age at booking), (3) obstetrical complications (eg, postpartum hemorrhage), (4) medical complications (eg, pulmonary embolus, sepsis), (5) care requirements (eg, level of care, transfer to tertiary unit), and (6) trimester during which SMM occurred.

Following compilation and coding of all data, descriptive statistics were performed. Ethical approval was received from the Research Advisory Group, a subcommittee of the Research Ethics Committee, Rotunda Hospital, Dublin.

Results
Over the 8-year period, there were 81,504 women who received maternity services at our hospital, including 67,894 births. The trends for these are shown in Figure 1, which shows a slight downward trend in both maternity services and births over the last 8-years, excluding an increase in maternity cases in 2019.

Figure 2 demonstrates the SMM event rate during this period compared with the institutional corrected perinatal mortality rate. The latter has remained static over the last number of years, with the SMM event rate showing a peak in 2017, followed by a plateau in 2018 and 2019. Of note, there are differences between the SMM event rate and reportable SMM, because some women experienced multiple SMM events during the same pregnancy and because of changes in the

FIGURE 1
Trend of maternities and births between 2012 and 2019

McCarthy. A review of maternal morbidity. Am J Obstet Gynecol Glob Rep 2022.
reporting structure. However, when comparing the SMM event rate with the SMM per person rate, there is an evident correlation between the 2, apart from in 2017 when there was a peak in SMM events. SMM events were more common during the summer months with a peak in August (more than 2 standard deviations above the mean) as seen in Figure 3.

Maternal demographics
The Table 1 contains the maternal demographic information of the women who were categorized as being affected by 1 or more SMMs during the study period. There has been no significant change in the mean maternal age, however, there seems to be an increase in the number of non-Irish women who have suffered a morbidity. Overall, women with a multiple pregnancy were more likely to have an
SMM when compared with the institutional background rate of multiple pregnancy (2.88%; n=294).12 Overall, only 6.9% (n=35) of women attended the hospital for the first time in their pregnancy after 20 weeks’ gestation. On average, 61.2% (n=284) of women were recorded to be Irish, which is similar to institutional rates for 2019 (64%; n=5322),12 showing the diverse nature of the ethnicity of women attending our unit.

**Severe maternal mortality characteristics**

Overall, there were 504 women affected by SMM over the 8-year period, the majority of whom were attending our hospital for antenatal care (overall 88.4%; n=446); the remainder were transferred from peripheral hospitals because of the expertise within our center.

The graphical distribution of the 4 most frequent SMM events are shown in Figure 4. When reviewing the other most common SMM events, there were only 5 cases of acute myocardial infarction and 12 pulmonary emboli meeting the criteria for SMM during the study period. There were also 10 eclamptic seizures during the study period.

In Figure 4, we can see that both postpartum hemorrhage and hypertensive disorders of pregnancy account for a large proportion of the SMM events that occurred in our unit with 80 cases being categorized as having both a postpartum hemorrhage and a hypertensive disorder of pregnancy. Over recent years, there has been a reduction in the latter in specifically, whereas postpartum hemorrhage rates remained fairly static. Acute kidney injury rates have increased over recent years and sepsis rates have remained consistent.

Of those with SMM, just <1 in 5 (19.4%; n=98) required transfer to an affiliated general hospital for either specialist services not available on-site or for escalation of care. There was significant variation in this figure, with 6.8% (n=4) requiring transfer in 2013.
compared with 33.8% (n=22) and 33.3% (n=23) in 2012 and 2019, respectively.

With regards to the escalation of care, on average, 2.9% (n=14) of women required admission to coronary care facilities with 12.0% (n=60) requiring level 3 or intensive care services. This number has increased in recent years, however, it is not possible to extrapolate the rationale for this. Women were most likely to experience a morbidity in the third trimester or postnatal period, with the number of patients experiencing first- and second-trimester morbidities remaining fairly consistent (average, 2.98% [n=15] and 6.35% [n=32], respectively). This is unsurprising given that the 2 most common SMMs affect those in the third trimester and postnatal period most often.

Discussion
Principal findings
Through this longitudinal review, we can see a relative stability in the maternal demographics of women who suffered from an SMM, yet there was an overall increase in the rate of SMM. At our institution, the perinatal mortality rate has remained reasonably static, as has the maternal mortality rate (with the last direct maternal death in 2014).

Results
It is important to review this in the context of a gradual decline in the maternity cases and birth rates overall, because it highlights the importance of focusing on preventable morbidities and interventions to prevent these. It is interesting that non-Irish women and those with multiple pregnancies have a higher rate of SMM, and thus, a focus should potentially need to be placed on these 2 cohorts of women to examine further the morbidities that they experience and other confounding factors. In relation to multiple pregnancies, it would be interesting to ascertain if these were assisted or spontaneous conceptions (not currently recorded) and what comorbidities these women had when entering pregnancy that may have contributed to the development of an SMM event. This also has been demonstrated in previous studies of maternal morbidities in multiple pregnancies, with a 4-fold increased risk for SMM being reported for multiple pregnancies. In addition, in accordance with other international findings, minority ethnic groups have a higher rate of SMM. An institutional focus on the non-Irish cohort of women with an SMM may reveal if language barriers play a role in the timely detection of an SMM or if preexisting medical comorbidity rates are higher among these populations than the background population.

Clinical implications
Looking at the most suitable comparator, the annual SMM report from the National Perinatal Epidemiology Centre also reports that more than 20% of women experience more than 1 morbidity with a steady increase from 2011 to 2018. Our SMM person rate is also comparable to national rates, showing that these data are accurate despite differences in reporting criteria through the years. In our data set, we specifically recorded hypertensive disorders of pregnancy, HELLP syndrome, and eclampsia. The latter is the only parameter recorded in the national database with direct relation to hypertensive disorders of pregnancy, however, renal and liver dysfunction are also included in this. Excluding these institutional data, our most common SMM event was massive obstetrical hemorrhage, which has been a focus of quality improvement measures over the last number of years. The mean age of women in our cohort was slightly lower, and we have a slightly higher number of non-Irish women attending our services, which is most likely based on the demographics of our catchment area. However, these rates do compare favorably with SMM rates in Canada and the United States, which have higher SMM rates.

Research implications
Previous global reviews of SMM have implored for consistency in the reporting of SMM, yet these calls have remained largely unanswered. Core outcome sets have been created with the aim of gaining international consensus, but countries, and indeed individual hospitals, continue to collect data using their own criteria, such as at our institution.

Strengths and limitations
This study provides a novel look into SMM at a large tertiary maternity hospital over an 8-year period. It investigated a number of variables that are less often studied, such as month and trimester of morbidity, which may help to direct service planning into the future. In addition, our data corroborates with those published nationally, showing that they may be representative and thus reproducible at other institutions. However, despite this study collecting a large number of variables, there are still limitations in the analyses that were performed, and additional prospective work would be beneficial to examine particular associations that may be evident, such as with multiple pregnancies and the temporal changes in SMM throughout the year. The addition of variables and, in particular, the sparsity of information available for the initial year of our study is also a limitation of our work.

Conclusion
SMM should be seen as an essential quality indicator internationally, and we add to calls for an increased focus on SMM to reduce morbidities, which in turn would hopefully lead to a further reduction in mortalities and an overall improvement in the quality of care for the women, families, and infants we care for. Through the provision of increased resources aimed at specific areas of maternal care, as has happened with massive obstetric hemorrhage, we can continue to provide a safe environment for women to give birth, while limiting the complications that might befall them or at least minimize the severity of these.

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