Intensive Care Med (2010) 36:1465–1474
DOI 10.1007/s00134-010-1951-0

REVIEW

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Pregnant and postpartum admissions to the intensive care unit: a systematic review

Received: 2 September 2009
Accepted: 27 May 2010
Published online: 15 July 2010

Dr. Wendy Pollock prepared the bulk of her contribution to this manuscript whilst at The University of Melbourne.

Electronic supplementary material The online version of this article (doi:10.1007/s00134-010-1951-0) contains supplementary material, which is available to authorized users.

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Abstract *Purpose:* To determine the incidence and characteristics of pregnant and postpartum women requiring admission to an intensive care unit (ICU). *Methods:* Medline, PubMed, EMBASE and CINAHL databases (1990–2008) were systematically searched for reports of women admitted to the ICU either pregnant or up to 6 weeks postpartum. Two reviewers independently determined study eligibility and abstracted data. *Results:* A total of 40 eligible studies reporting outcomes for 7,887 women were analysed. All studies were retrospective with the majority reporting data from a single centre. The incidence of ICU admission ranged from 0.7 to 13.5 per 1,000 deliveries. Pregnant or postpartum women accounted for 0.4–16.0% of ICU admissions in study centres. Hypertensive disorders of pregnancy were the most prevalent indication for ICU admission [median 0.9 cases per 1,000 deliveries (range 0.2–6.7)]. There was no difference in the profile of ICU admission in developing compared to developed countries, except for the significantly higher maternal mortality rate in developing countries (median 3.3 vs. 14.0%, $p = 0.002$). Studies reporting patient outcomes subsequent to ICU admission are lacking. *Conclusions:* ICU admission of pregnant and postpartum women occurs infrequently, with obstetric conditions responsible for the majority of ICU admissions. The ICU admission profile of women was similar in developed and developing countries; however, the maternal mortality rate remains higher for ICUs in developing countries, supporting the need for ongoing service delivery improvements. More studies are required to determine the impact of ICU admission for pregnant and postpartum women.

Keywords Critical care · Intensive care · Severe maternal morbidity · Severe obstetric morbidity · Near miss

Introduction

Mortality remains the sole metric for maternal health in many countries despite low and stable rates in developed countries [1]. Severe maternal morbidity has been proposed as an indicator for quality maternal services because of its higher incidence and focus on interventions designed to improve maternal health [2–6]. The prevalence of severe maternal morbidity remains controversial due to variability in definitional criteria and a lack of established databases to capture information specific to this patient population. Admission to an intensive care unit (ICU) may be considered an objective marker of severe maternal morbidity [7, 8]; however, admission criteria vary among institutions, regions and countries, introducing heterogeneity [9].

ICU admission of pregnant and postpartum women presents significant challenges to ICU clinicians because of altered maternal physiology, fetal considerations and medical emergencies associated with pregnancy. Over a decade ago, Scarpinato [10] identified a lack of empirical data regarding obstetric critical care and called for an increase in reporting. Since then, several studies have been published reporting the prevalence of obstetric critical care admission and the various characteristics of women admitted to an ICU during pregnancy or within 6 weeks of delivery. The objective of this systematic review was to synthesize studies reporting the incidence and characteristics of pregnant and postpartum women requiring ICU admission. These data will enable a better understanding of the clinical profile of this unique ICU population and help to determine the utility of the criterion of ICU admission as a marker of severe maternal morbidity.

Methods

Search strategy

The databases Medline, PubMed, EMBASE and CINAHL were searched from January 1990 to November 2008. To identify studies pertinent to our study population, the following search terms were used in combination: obstetrics; pregnancy complications; intensive care; critical care. The search also incorporated the following search terms: severe obstetric morbidity; severe acute maternal morbidity; postnatal morbidity; near miss; severe maternal morbidity; postpartum morbidity. For the purposes of this review, publications prior to 1990 and non-English articles were excluded. Two authors independently reviewed all citations retrieved from the electronic search to identify potentially relevant studies.

Study selection

Abstracts of references obtained via database and hand searching were independently examined by two investigators (LR and WP). Studies were included that reported data from women admitted to an ICU either pregnant or up to 6 weeks postpartum. Exclusion criteria were (1) studies that did not report one of the following (a) the number of deliveries or (b) the total number of ICU admissions during the data collection period; (2) reports from ICUs located within an obstetric unit; (3) letters, reviews, case studies and editorial comments. Inter-rater agreement for study inclusion was very good (κ 0.88; 95% CI 0.71–1.00). Disagreements were resolved by discussion.

Data extraction

Using a standardized data extraction form, data related to study design, duration, location, incidence of ICU admission, ICU length of stay, severity of illness, age, medical and obstetric data, perinatal outcome and diagnoses responsible for ICU admission were recorded. Additionally, studies were examined to determine if patient outcomes relating to physical, psychological and postpartum adaptation after ICU discharge had been evaluated. Two investigators (LR and WP) independently extracted all data items to verify accurate extraction of data in keeping with the recommendations of the Cochrane Collaboration [11].

Due to the heterogeneity of reporting causes of severe maternal morbidity, reasons for ICU admission were categorized as follows: (1) hypertension of pregnancy incorporating preeclampsia, eclampsia and HELLP syndrome; (2) obstetric haemorrhage; (3) sepsis; (4) other direct obstetric complications; (5) non-direct obstetric diagnoses or complications; (6) anaesthetic complications. Obstetric haemorrhage included antepartum, intrapartum and postpartum causes as reported by individual studies. Other direct obstetric complications included pulmonary embolism, pulmonary oedema, acute fatty liver of pregnancy, amniotic fluid embolism, abortion, abnormal adherence of placenta, intrauterine fetal death, gestational diabetes and peripartum cardiomyopathy. Non-direct obstetric diagnoses or complications were all other cases not identified as one of the above, including medical conditions and those cases categorised as organ or system failure. All data were independently checked by a third investigator (CLD).

Data analysis and synthesis

Continuous variables including the duration of data collection, study participant numbers, ICU length of stay and severity of illness scores were summarized using mean and standard deviations or medians and either range (minimum–maximum) or interquartile range dependent on the distribution and presentation of data. We categorized studies arising from developed regions versus developing regions as classified by the United Nations [12]. Comparisons between studies from developed and developing countries were made using Mann-Whitney U tests or Student's t tests according to data distributions.

If not reported, we determined the incidence per 1,000 deliveries of identified causes of maternal morbidity by dividing the reported number of cases by the total number of reported deliveries during the study duration and multiplying by 1,000. The number of women admitted to the ICU per 1,000 deliveries was calculated in a similar manner. To report an overall ICU length of stay and severity of illness, we summarized studies reporting either the mean or median value [11].

Results

Limiting to English language publications from 1990 to 2008 resulted in the identification of 1,052 potential articles; many screened articles reported the neonatal ICU population as opposed to maternal admission to ICU. On completion of screening, 45 studies were identified for detailed evaluation, 11 of which were excluded, and a further 6 studies were identified through hand searching the reference lists of relevant articles (Fig. 1). Details of the 11 excluded studies are available in an electronic supplement on the journal website.

Study characteristics

The 40 eligible studies reported data on 7,887 women admitted to ICU from 2,096,634 deliveries [number of deliveries reported in 35 (87.5%) studies]. Twenty-four (60.0%) studies reported data from developed countries, 15 (37.5%) from developing countries, and 1 (2.5%) from the US and India (developed and developing). All 40 studies used a retrospective design; 37 (92.5%) were observational cohort studies, and 3 (7.5%) used a case control design [7, 26, 40]. Four studies described retrospective analyses of either regional [7, 26, 40] or national databases [41], two studies reported ICU data from two

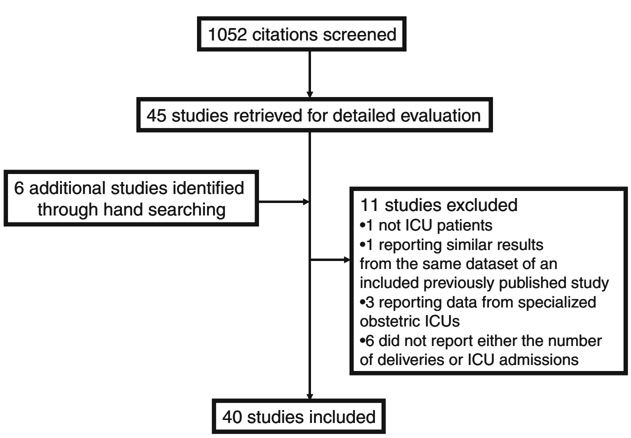

Fig. 1 Study identification

hospitals [24, 39], and the remainder were single-centre surveys. The median number of participants was 65 (IQR 44–171) with a mean study duration of 6.7 ± 3.5 years (Table 1).

The definition of study participants varied. Eleven (27.5%) studies defined participants as pregnant and ≤6 weeks postpartum [7, 14, 19, 29, 31, 33, 36, 39, 43, 47, 48], five (12.5%) as pregnant and variations up to 4 weeks postpartum [13, 25, 28, 32, 42], and four (10%) studies defined cases as either ≥14 or 16 weeks gestation and ≤6 weeks postpartum [16, 24, 40, 45]. Four (10%) studies defined cases based on the admitting unit or transfer from a stand-alone women's hospital [4, 22, 30, 49], and two (10%) studies used only obstetric diagnostic codes [26, 41]. The remaining 14 (35%) studies defined their cases as 'obstetric' or 'parturient' with no further detail. Only 15 (37.5%) studies described the method of case identification: seven by hospital-based ICU or perinatal databases [4, 16, 24, 32, 33, 40, 43], four by the admitting unit designation [22, 30, 42, 49], and four by identifying eligible cases in regional administrative or critical care databases [7, 26, 29, 41]. The remaining 25 (62.5%) studies did not state how they identified cases: general statements, such as cases were identified and the medical records reviewed, were common. One study described using ascertainment and verification strategies, but failed to report if these strategies identified additional or erroneous cases [8].

Patient characteristics

Overall, 35 studies reported the incidence of ICU admission per 1,000 deliveries. The median incidence was 2.7/1,000 deliveries (IQR 1.9–5.4), which equates to 1 ICU admission per 370 deliveries (Table 1). Twenty-one studies reported the total number of ICU admissions with pregnant or postpartum women accounting for 0.4–16.0% of all ICU admissions [median 2.2% (IQR 0.9–3.3%)]. Data on severity of illness were reported by 21 studies with the APACHE II score most frequently reported. Maternal deaths following maternal ICU admission occurred in all but four studies [13, 21, 28, 48], with the mortality rate ranging from 0 to 40% [46].

The primary cause of ICU admission was a condition directly related to pregnancy in the majority of studies at 1.9 per 1,000 deliveries. The core conditions were hypertensive disorders of pregnancy (preeclampsia, eclampsia and HELLP syndrome), median 0.9 cases per 1,000 deliveries (range 0.2–6.7), followed by obstetric haemorrhage [0.7/1,000 deliveries (range 0.1–2.3)], with sepsis [0.2/1,000 deliveries (range 0.0–2.3)] and other direct obstetric complications [0.1/1,000 deliveries (range 0.0–1.6)] occurring less frequently (Table 2). Non-direct obstetric diagnoses were relatively frequent [0.9/1,000 deliveries (range 0.1–3.0)] whilst anaesthetic complications

Table 1 Studies reporting ICU admissions for pregnant and postpartum women

Study	Country	Data collection period (years)	*N*	Incidence/ 1,000 deliveries	Proportion ICU admissions (%)	ICU length of stay (days)	Severity of illness[a]	Maternal deaths, *n* (%)
Stephens [13]	Australia	10.0	126	2.1	NR	NR	NR	0 (0)
Kilpatrick [14]	USA	5.0	32	4.0	NR	5.4 ± 7.5[b]	NR	4 (12.5)
Ng [15]	Singapore	5.0	37	2.3	3.0	NR	NR	2 (5.4)
Monaco [16]	USA	8.0	38	2.5	NR	5.4 (1–20)[c]	NR	7 (18.4)
Lewinsohn [17]	Israel	8.0	58	NR	3.5	NR	11[b]	4 (6.9)
Umo-Etuk [18]	UK	5.0	39	6.8	NR	2.0 (0.5–13)[c]	NR	1 (2.3)
Wheatley [19]	UK	5.0	144	7.6	12	3.0 (1–19)[c]	NR	3 (2.1)
Bouvier-Colle [7]	France	NR	435	3.1	NR	4.2[b]	4.8[b] SAPS	22 (5.1)
Bewley [20]	UK	2.0	30	5.0	NR	2.0 (1–14)[c]	NR	2 (6.6)
Lapinsky [21]	Canada	5.0	65	2.6	NR	2.9 ± 2.1[b]	6.8 ± 4.2[b]	0 (0)
Platteau [22]	South Africa	1.0	80	NR	8.7	4.4 ± 4.4[b]	NR	21.3
Tang [23]	China	8.0	49	1.3	0.61	4.1 ± 2.3[b]	12.7[b]	2 (4.1)
Baskett [4]	Canada	14.0	55	0.7	NR	NR	NR	2 (3.6)
Mahutte [24]	Canada	6.0	131	3.0	NR	2.5 ± 3.0[b]	8.5 ± 4.8[b]	3 (2.3)
Cohen [25]	Israel	4.0	46	2.4	2.3	1.0 ± 3.4[b]	6.0 ± 3.9[b]	1 (2.2)
Panchal [26]	USA	14.0	1,023	1.2	NR	2.0 (1–38)[c]	NR	34 (3.3)
Tripathi [27]	India	5.0	50	1.9	NR	1.4[b]	NR	14 (28)
Al-Jabari [28]	Saudi Arabia	3.0	65	NR	0.5	1 (1–6)[c]	NR	0 (0)
Hazelgrove [29]	UK	3.0	210	1.7	1.8	1.0 (1–34)[c]	9.0[c]	7 (3.3)
Loverro [30]	Italy	11.0	41	1.7	NR	5.1 ± 3.4[b]	NR	2 (4.9)
Quah [31]	Singapore	2.0	232	7.5	NR	1.6[b]	NR	3 (1.3)
Cheng [32]	Singapore	5.0	43	3.2	1.1	3.0 (1–21)[c]	7.0 (0–22)[c]	2 (4.7)
Murphy [33]	UK	12.0	50	1.0	NR	1.0[b] (range 1–48)	NR	3 (6)
Demirkiran [34]	Turkey	5.0	125	8.9	2.6	S: 4 ± 5[b] NS: 8 ± 10[b]	S: 12.0 ± 5[b] NS: 25.0 ± 8[b]	13 (10.4)
Gilbert [8]	USA	8.0	233	4.7	NR	4.1 ± 9.5[b]	17.0 (4–74)[c]	8 (3.4)
Anwari [35]	Saudi Arabia	6.0	99	2.0	1.6	2.0 (1–2)[c]	NR	1 (1)
Karnad [36]	India	5.0	453	5.5	NR	4.0 (IQR 2–6)[c]	S: 14.0 (8–20)[c] NS: 28.0 (20–35)[c]	98 (21.6)
Mirghani [37]	UAE	6.0	60	2.6	2.4	1.6 ± 1.5[b]	5.0 ± 3.0[b]	2 (3.3)
Okafor [38]	Nigeria	6.0	18	2.8	2.2	2.5[b]	NR	6 (33)
Munnur [39]	USA and India	10.0	174 754	3.0 (USA) 4.8 (India)	NR	3.0 (IQR 2–4)[c] 4.0 (IQR 3–5)[c]	10.0 (IQR 7–13)[c] 16.0 (IQR 10–24)[c]	4 (2.3) 189 (25)
Selo-Ojeme [40]	UK	11.0	33	1.1	0.8	8.8 ± 9.3[b]	NR	1 (3.0)
Harrison [41]	UK	8.5	1,902	NR	0.9	S: 1.1 (0.7–2.3)[c] NS: 1.3 (0.5–4.5)[c]	10.9 (5.4–16.4)[c]	44 (2.3)
Rajab [42]	Kingdom of Bahrain	5.0	83	1.6	3.0	Range 1–12	18.7[b]	4 (4.8)
Al-Suleiman [43]	Saudi Arabia	12.0	64	2.2	NR	6.5 (range 1–36)[b]	NR	6 (9.4)
Keizer [44]	The Netherlands	12.0	142	7.6	0.7	4.5 (1–58)[c]	NR	7 (4.9)
Mjahed [45]	Morocco	8.0	364	6.2	16	5.7 ± 5[b]	12.0 ± 5[b]	61 (16.8)
Tempe [46]	India	2.5	57	2.5	NR	S: 2 (1–16)[c] NS: 1 (1–2)[c]	S: 23.0 (9–43)[c] NS: 40.0 (23–71)[c] SAPS II	23 (40)
Vasquez [47]	Argentina	7.5	161	7.0	10.2	6 (IQR 3–11)[c]	14.0 ± 8 [b]	18 (11.2)
Sriram [48]	Australia	8.5	56	NR	0.4	NR	NR	0 (0)
Bibi [49]	Pakistan	1.0	30	13.5	1.3	NR	NR	10 (33)

NR not reported, *S* survivors, *NS* non-survivors; *UAE* United Arab Emirates, *IQR* interquartile range

[a] Severity of illness scores are APACHE II unless otherwise indicated

[b] Mean ± SD unless otherwise indicated

[c] Median [range (unless otherwise indicated)]

were very uncommon [0.0/1,000 deliveries (range 0.0–1.0)]. Specific non-direct obstetric diagnoses were listed in 14 studies only and accounted for between 9 and 45% of the study population; median 27% (IQR 16–38%). Specific conditions, such as pneumonia, were commonly not listed individually, with generic categories, such as respiratory, listed instead. Consequently, the presentation of data on 'non-direct obstetric diagnosis' and 'medical conditions' varied between studies to the degree that further analysis was not feasible.

Table 2 Causes of severe maternal morbidity resulting in ICU admission

Study	Deliveries (*N*)	Hypertensive disease of pregnancy		Obstetric haemorrhage		Sepsis/infection		Other direct obstetric complications		Non-direct obstetric diagnoses		Anaesthetic complications	
		n (%)	/1,000	*n* (%)	/1,000	*n* (%)	/1,000	*n* (%)	/1,000	*n* (%)	/1,000	*n* (%)	/1,000
Stephens [13]	61,435	30 (24)	0.49	28 (22)[c]	0.46	12 (9.5)[f]	0.20	5 (4)	0.08	35 (28)	0.57	16 (12.5)	0.26
Kilpatrick [14]	8,000	7 (22)	0.88	4 (12.5)[c]	0.50	5 (15.5)[f]	0.63	5 (15.5)	0.63	11 (34.5)	1.38	0 (0)	0.00
Ng [15]	16,264	10 (27)	0.61	7 (19)[a]	0.43	0 (0)	0.00	4 (11)	0.25	8 (22)	0.49	8 (22)	0.49
Monaco [16]	15,323	12 (32)	0.78	2 (5)[b]	0.13	2 (5)[f]	0.13	3 (9)	0.20	18 (47)	1.17	1 (2)	0.07
Lewinsohn [17]	–	16 (28)	–	11 (19)[c]	–	14 (24)[f]	–	0 (0)	–	13 (22)	–	4 (7)	–
Umo-Etuk [18]	5,764	12 (31)	2.08	12 (31)[c]	2.08	5 (13)[f]	0.87	0 (0)	0.00	10 (25)	1.73	0 (0)	0.00
Wheatley [19]	19,020	80 (59)	4.21	23 (17)[c]	1.21	1 (0.5)[f]	0.05	2 (1.5)	0.11	26 (19)	1.37	4 (3)	0.21
Bouier-Colle [7]	–	120 (28)	–	92 (21)[a]	–	20 (5)[e]	–	74 (17)	–	123 (28)	–	6 (1)	–
Bewley [20]	6,039	14 (46.5)	2.32	14 (46.5)[c]	2.32	3 (10)[f]	0.50	2 (6.5)	0.33	8 (26.5)	1.32	0 (0)	0.00
Lapinsky [21]	25,000	23 (35.5)	0.92	11 (17)[c]	0.44	2 (3)[e]	0.08	10 (15.5)	0.40	19 (29)	0.76	0 (0)	0.00
Platteau [22]	–	55 (69)	–	7 (8.5)[a]	–	6 (7.5)[f]	–	3 (4)	–	9 (11)	–	0 (0)	–
Tang [23]	39,350	7 (14)	0.18	26 (53)[b]	0.66	0 (0)	0.00	0 (0)	0.00	9 (18)	0.23	7 (14)	0.18
Baskett [4]	76,119	14 (25)	0.18	12 (22)[a]	0.16	8 (15)[f]	0.10	6 (11)	0.08	15 (27)	0.20	0 (0)	0.00
Mahutte [24]	44,340	28 (22)	0.65	34 (26)[a]	0.77	13 (10)[f]	0.29	7 (5)	0.16	49 (37)	1.11	0 (0)	0.00
Cohen [25]	19,474	15 (33)	0.77	11 (24)[a]	0.56	3 (6.5)[f]	0.15	2 (4)	0.10	11 (24)	0.56	4 (8.5)	0.21
Panchal [26]	822,591	374 (28)	0.45	451 (33.5)[a]	0.55	53 (4)[f]	0.06	58 (4)	0.07	371 (27.5)	0.45	45 (3)	0.05
Tripathi [27][g]	26,986	9 (18)	0.33	14 (28)[c]	0.52	8 (16)[f]	0.30	0 (0)	0.00	5 (10)	0.19	13 (26)	0.48
Al-Jabari [28]	–	14 (21.5)	–	20 (31)[a]	–	1 (1.5)[e]	–	5 (8)	–	23 (35)	–	2 (3)	–
Hazelgrove [29]	122,850	83 (40)	0.68	70 (33)[a]	0.57	5 (2.5)[f]	0.04	3 (1.5)	0.02	49 (23)	0.28	0 (0)	0.00
Loverro [30]	23,694	31 (75.5)	1.31	6 (14.5)[c]	0.25	0 (0)	0.00	2 (5)	0.08	2 (5)	0.08	0 (0)	0.00
Quah [31][d]	31,725	116 (39.5)	3.66	55 (19)[c]	1.73	7 (2.5)[f]	0.22	16 (5.5)	0.50	95 (32.5)	2.99	3 (1)	0.09
Cheng [32]	13,438	15 (40)	1.12	17 (35)[a]	1.27	0 (0)	0.00	2 (4.5)	0.15	7 (16)	0.52	8 (18.5)	0.60
Murphy [33]	51,576	16 (32)	0.31	12 (24)[a]	0.23	3 (6)[f]	0.06	4 (8)	0.08	14 (28)	0.27	1 (2)	0.02
Demirkiran [34]	4,733	92 (74)	6.55	14 (11)[a]	1.00	3 (2.5)[f]	0.21	2 (1.5)	0.14	14 (11)	1.00	0 (0)	0.00
Gilbert [8]	49,349	48 (21)	0.97	56 (24)[b]	1.13	8 (3.5)[e]	0.16	29 (12.5)	0.59	92 (39)	1.86	0 (0)	0.00
Anwari [35]	46,428	29 (29.5)	0.62	28 (28)[c]	0.60	0 (0)	0.00	0 (0)	0.00	42 (42.5)	0.90	0 (0)	0.00
Karnad [36]	82,623	253 (56)	3.06	78 (17)[a]	0.94	28 (6)[e]	0.34	134 (30)	1.62	176 (39)	2.13	0 (0)	0.00
Mirghani [37]	23,383	15 (25)	0.64	17 (28)[c]	0.73	0 (0)	0.00	3 (5)	0.13	25 (42)	1.07	0 (0)	0.00
Okafor [38]	6,544	9 (50)	1.38	4 (22)[a]	0.61	0 (0)	0.00	2 (11)	0.31	3 (16.5)	0.46	0 (0)	0.00
Munnur [39], India	157,694	385 (34)	2.44	185 (16)[a]	1.17	56 (5)[e]	0.36	167 (15)	1.06	341 (30)	2.16	0 (0)	0.00
Munnur [39], USA	58,000	105 (32)	1.81	51 (15.5)[a]	0.88	48 (14.5)[e]	0.83	40 (12)	0.69	86 (26)	1.48	0 (0)	0.00
Selo-Ojeme [40]	31,097	13 (39)	0.42	12 (36)[c]	0.39	0 (0)	0.00	2 (6)	0.06	6 (18)	0.19	0 (0)	0.00
Harrison [41][d]	–	727 (23.5)	–	624 (20)[a]	–	51 (1.5)[e]	–	1,721 (55)	–	450 (23.7)	–	0 (0)	–
Rajab [42]	52,806	10 (12)	0.19	23 (28)[a]	0.44	3 (3.5)[f]	0.06	7 (8.5)	0.13	36 (43)	0.68	4 (5)	0.08
Al-Suleiman [43]	29,432	11 (17)	0.37	21 (33)[a]	0.71	4 (6)[e]	0.14	0 (0)	0.00	25 (39)	0.85	3 (5)	0.10
Keizer [44]	18,581	88 (62)	4.74	26 (18)[c]	1.40	4 (3)[f]	0.22	5 (3.5)	0.27	18 (13)	0.97	1 (0.5)	0.05
Mjahed [45]	58,708	257 (71)	4.38	59 (16)[b]	1.00	14 (4)[f]	0.24	8 (2)	0.14	24 (6.5)	0.41	2 (0.5)	0.03
Tempe [46]	23,000	17 (30)	0.74	21 (37)[a]	0.91	4 (7)[e]	0.17	9 (15.5)	0.39	4 (7)	0.17	2 (3.5)	0.09
Vasquez [47]	23,044	64 (40)	2.78	26 (16)[c]	1.13	26 (16)[e]	1.13	5 (3)	0.22	40 (25)	1.74	0 (0)	0.00
Sriram [48]	–	27 (48)	–	20 (36)[a]	–	3 (5)[f]	–	9 (16)	–	0 (0)	–	0 (0)	–
Bibi [49]	2,224	15 (50)	6.74	4 (13.5)[c]	1.80	5 (17)[e]	2.25	2 (6.5)	0.90	3 (10)	1.35	1 (3)	0.45

Other obstetric causes included pulmonary embolism, pulmonary oedema, acute fatty liver of pregnancy, amniotic fluid embolism, abortion, abnormal adherence of placenta, intrauterine fetal death, gestational diabetes and peripartum cardiomyopathy. Non-obstetric causes included indications listed by system and not otherwise identified as one of the above conditions

[a] Obstetric haemorrhage includes antepartum, intraoperative and postpartum

[b] Postpartum haemorrhage only

[c] Timing of haemorrhage not stated

[d] Data denote frequency of disorders not number of cases

[e] Puerperal/obstetric causes

[f] Causes not defined

[g] Note data reported in paper do not equate to 100% of cases identified

Table 3 Characteristics of study participants

Descriptor	Number of studies reporting data item (out of 40)	Median	Range	IQR
Mean age (years)	25	30	23–33	26–31
≥35 years of age	6	22%	6–33%	15–31%
Primipara	14	50%	27–76%	46–55%
Pregnant on admission to ICU	25	16%	1–45%	6–28%
Caesarean delivery	24	70%	15–95%	58–80%
Perinatal mortality	22	20%	0–52%	11–32%
Transferred to access ICU bed	14	23%	1–100%	13–79%
ICU length of stay <24 h	7	45%	38–65%	42–62%

Table 4 Characteristics of included studies according to country level of development

Characteristic ($N = 41$)[a]	Developing[b] ($n = 16$)	Developed[b] ($n = 25$)	p value
Study duration (years), mean ± SD	5.4 ± 2.9	7.4 ± 3.6	0.06
Participants	73 (30–1,902)	65 (18–754)	0.81
Deliveries during study period	28,209 (5,764–822,591)	24,347 (2,224–82,623)	0.92
Incidence of ICU admission during study period	2.7 (1.3–13.5)	3.0 (0.7–8.8)	0.52
Maternal deaths (%)	14.0 (0.0–40.0)	3.4 (0.0–18.4)[c]	0.002
Overall proportion of ICU admissions (%)	2.4 (0.5–16.0)	1.5 (0.4–12.0)	0.38
Received mechanical ventilation (%)	41.0 (3.0–100.0)	41.5 (13.0–76.0)	0.60
Hypertensive disease of pregnancy (%)	39.8 (10.0–74.0)	32.5 (13.0–88.0)	0.93
Hypertensive disease of pregnancy (per 1,000 deliveries)	1.1 (0.2–6.7)	0.9 (0.2–4.7)	0.75
Obstetric haemorrhage (%)	25.0 (8.5–53.0)	21.5 (5.0–46.5)	0.85
Obstetric haemorrhage (per 1,000 deliveries)	0.8 (0.4–1.8)	0.6 (0.1–2.3)	0.27
Sepsis/infection (%)	5.0 (0.0–17.0)	4.8 (0.0–24.0)	0.85
Sepsis/infection (per 1,000 deliveries)	0.2 (0.0–2.3)	0.1 (0.0–0.9)	0.62
Other direct obstetric complications (%)	4.5 (0.0–30.0)	5.8 (0.0–55.0)	0.31
Other direct obstetric complications (per 1,000 deliveries)	0.1 (0.0–1.6)	0.2 (0.0–3.4)	0.95
Non-obstetric diagnoses (%)	21.5 (6.5–43.0)	25.8 (0.0–47.0)	0.92
Non-obstetric diagnoses (per 1,000 deliveries)	0.9 (0.2–2.2)	0.7 (0.0–3.0)	0.99
Anaesthetic complications (%)	0.3 (0.0–26.0)	0.0 (0.0–22.0)	0.83
Anaesthetic complications (per 1,000 deliveries)	0.0 (0.0–0.5)	0.0 (0.0–0.6)	0.71

All values are medians and ranges unless otherwise indicated

[a] Study by Munnur et al. [39] included as two studies as comparative data is reported from both the United States and India

[b] As classified by the United Nations [12]

[c] p value 0.002 determined by Mann-Whitney U test due to non-normal distribution of data. All other differences between developed and non-developed countries were not statistically significant

Individual characteristics were variously reported in the 40 studies with data on age, primipara status and pregnant when admitted to ICU incompletely reported (Table 3). The mode of delivery was also variously reported, with 24 studies reporting some data on caesarean section delivery. These data were sometimes restricted to those admitted to ICU postpartum, with not all women in the study followed up for delivery outcome. Likewise, perinatal outcome was inconsistently reported with foetal mortality [49], neonatal mortality [47] and perinatal outcome up to hospital discharge [45] variously reported. The perinatal mortality (inclusive of any fetal and neonatal defined deaths) was reported in some form in 22 studies (Table 3).

Similarly, there was incomplete reporting of ICU service utilization data, including the proportion of women transferred to the study hospital to access an ICU bed and women who remained in ICU for <24 h (Table 3). The proportion of women who received mechanical ventilation was reported in 29 studies. The median proportion of women receiving ventilation was 41% with a range of 3% (37) to 100% (28) (IQR 24–59%), which was not significantly different in developed and developing countries (Table 4). Notably, only one study reported the proportion of women who were planned ICU admissions, which made up 18% of that study's population [37].

Comparisons between developed and developing countries

There was no difference in the incidence of ICU admissions per 1,000 deliveries in reports from developed (median 3.0%, range 0.7–8.8%) and developing countries [median 2.7%, range 1.3–13.5% ($p = 0.5$)] or the profile of primary indications for ICU admission (Table 4). The number of maternal deaths in ICU differed significantly [median 3.4%, range 0.0–18.4 vs. 14.0%, 0.0–40.0 ($p = 0.002$)] (Table 4). The reported severity of illness of women presenting to ICU in developing countries was higher than in developed countries (mean difference in APACHE II scores 8.0, 95% CI 2.3–13.7, $p = 0.01$).

Discussion

This systematic review confirms the low incidence of pregnant and postpartum women requiring admission to ICUs in both developed and developing countries. The median incidence of ICU admission for those studies reporting the total number of deliveries was 2.7/1,000, equating to 1 ICU admission for every 370 deliveries. The similarity in the incidence rate for developed and developing countries is somewhat surprising considering known differences in access to health care systems and availability of ICU services. Numbers of ICU beds per 100,000 population vary considerably between developed and developing countries; ICU beds number 2/100,000 population in developing countries like Peru [50] and Trinidad [51] compared with 30.5/100,000 in the US [52]. There is also considerable variation within developed countries. Australia, for example, has 7.5 ICU beds per 100,000 population compared to 28.6/100,000 in Germany [52]. One European study examining outcomes for women with severe preeclampsia, severe obstetric haemorrhage and sepsis reported high variability in ICU admission rates across nine countries, ranging from 0 to 50% of women [9]. This variability was explained by differing management protocols in obstetric units, ICU admission criteria and availability of ICU beds, and highlights the difficulty of using ICU admission as a sole criterion of severe maternal morbidity.

A key finding of this review was the predominance of retrospective studies. A major limitation of the retrospective design is the ability to identify cases accurately using existing hospital or ICU databases or medical records. Accordingly, identification of cases is dependent on accurate and consistent reporting of either the pregnant or postpartum status of the woman, a diagnosis flagged as an indicator such as hypertension of pregnancy, or a birth event. Thus, cases identified using a retrospective design may be skewed towards obstetric diagnoses with pregnant or postpartum women admitted to ICU with diagnoses unrelated to pregnancy not identified. Only 1 of the 40 studies in this review described any ascertainment strategy, which is of concern given the retrospective nature of the designs. It is possible that the reported studies do not reflect the reality of obstetric admissions to ICU, and it is likely that the incidence of ICU admission of pregnant and postpartum women has been under-reported in these retrospective studies. This would be in keeping with the noted persistent problem, even in developed countries, of under-ascertainment of maternal deaths [53].

Criteria used to define cases in the studies examined in this review were not consistent introducing disparities in the characteristics of included patients. For example, some studies included all pregnant women [36], whereas other studies excluded women <16 weeks pregnant [16]. The postpartum period was also variously defined as 1–6 weeks [24, 47]. Variable study populations and differing access to ICU beds make comparison of the ICU admission rate non-meaningful as a marker of severe maternal morbidity. To improve the utility of “admission to ICU by pregnant and postpartum women” as such a marker, there must be an agreed definition of the study population. Due to the potential for obstetric-related complications to occur late in the postpartum period, for example, eclampsia [54] and thrombosis [55], the most inclusive definition recommended for consideration for future studies is to include all pregnant women up to 6 weeks postpartum. Additionally, this inclusive definition is in keeping with the definition of timeframes for maternal mortality [53]. Along with inconsistent study population definition, there were also large variations in the variables collected and reporting format of results, making detailed comparison across studies somewhat difficult.

Almost uniformly in both developed and developing countries, the two most common causes of admission to ICU were the obstetric diagnoses, hypertensive disorders of pregnancy and obstetric haemorrhage, with the majority of all ICU admissions occurring during the postpartum period. Importantly, pre-existing or medical diseases were not major contributors to the reason for ICU admission; however, some studies excluded women with these conditions, and the retrospective nature of the studies may have missed potentially eligible women.

Neonatal outcome was variously reported by just over half the studies, with a perinatal mortality around 20%. Little has been reported on perinatal outcome aside from the study on the neonatal outcome of women admitted pregnant to ICU with non-obstetric diagnoses, which reported a neonatal mortality of 34% [56]. The study population in this study [56] was distinctly different form most of the studies in our systematic review given that most women in the systematic review were admitted to ICU postpartum and with primarily obstetric diagnoses. A large proportion of neonates in the study by Cartin-Ceba et al. [56] required admission to a neonatal ICU, and more detailed examination of neonatal outcome following all maternal ICU admission would be of value to enhance understanding of the impact of maternal critical illness on neonatal outcome.

Advanced maternal age is not uniformly associated with ICU admission [7, 26]. A median age of 30 years and about 22% of women ≥35 years are consistent with birth age patterns in developed countries [57]. However, a description of age in itself is not meaningful without reference to the broader birthing population context in which the study was conducted as there can be large variation in birth age patterns between countries. For the studies that reported primipara status, about half of all admissions were first time mothers. Primiparity is a well-accepted risk factor for hypertensive disorders of pregnancy [58], one of the main causes of admission to ICU. The reported caesarean section rate was high in women who required admission to ICU at about 70%. The influence of the caesarean section on maternal illness is not well understood as many women may have required a caesarean section because they were critically ill, whilst others may have become critically ill due to complications related to the caesarean section.

As anticipated, the maternal mortality rate for women admitted to ICUs in developed countries was low; the mortality rate in developing countries was considerably higher, consistent with the disproportionate burden of maternal mortality that the developing world carries [53, 59]. Although severity of illness scores were reported in only half of the studies, women in developing countries tend to be admitted to ICU in a more parlous state, which may account for the observed higher mortality rate. The higher mortality in developing countries may also indicate that women present late with complications and experience difficulties accessing health services, a finding observed in studies of maternal mortality [60]. Further differences in the populations of developed and developing countries could not be examined in detail in this study. Whilst hypertensive disorders of pregnancy and obstetric haemorrhage were consistently the main causes of admission to ICU, endemic infectious diseases, such as malaria, viral hepatitis and leptospirosis, were a cause of admission in developing countries that were absent in developed countries [39]. There was little direct reference to human immunodeficiency virus (HIV), an increasingly relevant cause of maternal death in developing countries. However, the causes of maternal mortality may not be similar to the causes of maternal ICU admission. Mantel and colleagues have shown that the conditions causing severe maternal morbidity are not always the same as those causing maternal mortality in developing countries. The same is true for developed countries where thromboembolism, for example, a leading cause of death, is not a major cause of ICU admission [53]. Furthermore, in the UK, only 30% of maternal mortality involved an ICU admission [53], and in developing countries, it is likely that most maternal mortality occurs without admission to ICU [61].

This systematic review has identified that current knowledge focuses on descriptive analyses of ICU utilization, risk factors for admission, and patient outcomes including ICU mortality and length of stay. There is little examination of service delivery issues in the identified studies. The adapted physiology of pregnancy, presence of the foetus, and specific conditions of pregnancy all contribute to make this patient population fundamentally different from other critically ill patients. These key differences give rise to potential concerns about service provision and form the basis for specialized service needs. There are no published studies investigating the potential service gap between maternity and ICU services. All studies examined in this review represent a snapshot in time of the ICU admission with virtually no data on hospital outcome, postpartum follow-up or interdisciplinary management.

Review of maternal deaths has found that up to 50% of deaths have preventable factors, such as failure to recognise severity of illness and delay in referral for intensive care services [53]. Early warning systems and critical care outreach services are recommendations proposed to further reduce maternal mortality and potentially reduce the requirement for ICU admission [53]. Research on the interface between maternity and intensive care services, such as systematic clinical audit including the 24 h prior to ICU admission, may assist with identification of optimal service delivery for women experiencing severe maternal morbidity [62]. Additionally, further research is warranted to determine the optimal location in a hospital for acutely ill pregnant and postpartum women. Many of the women in these studies stayed in ICU <24 h and did not require mechanical ventilation. It is possible that ICU admission could be avoided by up-skilling and developing maternity areas to cater for high dependency maternity patients [29].

A major limitation of this review was the exclusion of non-English language papers; it is possible that studies published in non-English journals may have presented a different picture from that found in this review. Likewise, although systematic efforts were made to identify all eligible studies, relevant studies may have been missed if they were published as reports by local health boards and the like. Studies in developing countries were under-represented given the volume of births and maternal deaths that occur in these countries compared to the developing world. A publication bias may have inhibited a full understanding of the differences in ICU admission between developing and developed countries, including the main causes of admission to ICU. A further limitation is the possibility that we have misclassified some of the causes of admission to ICU, given the inconsistent reporting of specific data and heterogeneity of the studies.

Conclusion

Numerous retrospective studies from several countries confirm pregnant and postpartum women contribute only a small proportion of cases to the overall ICU case mix in both developed and developing countries. Obstetric complications in previously well women consistently contributed the majority of causes of ICU admission. The overall incidence and profile of patient characteristics of ICU admission are remarkably consistent in developed and developing countries, with the exception of a notable difference in maternal mortality rates.

Variable inclusion criteria and case identification methods make comparisons of ICU utilisation problematic. ICU admission is potentially a useful indicator of severe maternal morbidity that captures data on women with the most severe disease. Uniform criteria are needed to describe this patient population before ICU admission can be used internationally as a marker of severe maternal morbidity.

Conflict of interest statement The authors have no potentially conflicting financial interests or any other actual or potential conflict of interest to be declared.

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