

Perimortem caesarean section – why, when and how

Chu, Justin; Hinshaw, Kim; Paterson-Brown, Sara; Johnston, Tracey; Matthews, Margaret; Webb, Julian; Sharpe, Paul

DOI:

[10.1111/tog.12493](https://doi.org/10.1111/tog.12493)

License:

None: All rights reserved

Document Version

Peer reviewed version

Citation for published version (Harvard):

Chu, J, Hinshaw, K, Paterson-Brown, S, Johnston, T, Matthews, M, Webb, J & Sharpe, P 2018, 'Perimortem caesarean section – why, when and how', *The Obstetrician and Gynaecologist*, vol. 20, no. 3, pp. 151-158. <https://doi.org/10.1111/tog.12493>

[Link to publication on Research at Birmingham portal](#)

Publisher Rights Statement:

Checked for eligibility: 10/11/2017

"This is the peer reviewed version of the following article: Chu JJ, Hinshaw K, Paterson-Brown S, Johnston T, Matthews M, Webb J, Sharpe P. Perimortem caesarean section – why, when and how. *The Obstetrician & Gynaecologist*. 2018; 20:151–158, which has been published in final form at: <https://doi.org/10.1111/tog.12493>. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Self-Archiving."

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

The Obstetrician & Gynaecologist.

[Manuscript title:] Perimortem caesarean section – why, when and how

[Running title:] Perimortem caesarean section

Author names and post nominal initials

Justin J Chu MBChB MRCOG PhD,^{a,*} Kim Hinshaw MBBS FRCOG,^b Sara Paterson-Brown MBBch FRCS FRCOG,^c Tracey Johnston MBChB MD FRCOG,^d Margaret Matthews MBBS FRCOG MA,^e Julian Webb MBBS FRCS (Ed) FRCEM,^f Paul Sharpe MBBS FRCA^g

^aAcademic Clinical Lecturer, Birmingham Women's Hospital, Edgbaston, Birmingham B15 2TG, UK

^bConsultant Obstetrician and Gynaecologist, City Hospitals Sunderland NHS Foundation Trust, Sunderland SR4 7TP, UK

^cConsultant Obstetrician, Queen Charlotte's Hospital Imperial NHS Trust, London W12 0HS, UK

^dConsultant in Maternal Fetal Medicine, Birmingham Women's Hospital, Edgbaston, Birmingham B15 2TG, UK

^eConsultant Obstetrician and Gynaecologist, Tunbridge Wells Hospital, Tunbridge Wells, Kent TN2 4QJ, UK

^fConsultant in Emergency Medicine, Surrey and Sussex Healthcare NHS Trust, East Surrey Hospital, Redhill RH1 5RH, UK

^gConsultant Obstetric Anaesthetist, University Hospitals of Leicester NHS Trust, Leicester Royal Infirmary, Leicester LE1 5WW, UK

*Correspondence: Justin J Chu. Email: j.j.chu@bham.ac.uk

Disclosure of interests

KH, SP-B and PS are members of the MOET UK Working Group. KH is Chair of the UKOSS Steering Committee. [JJC, TJ, MM and JW have no competing interests to disclose.](#)

Contributions to authorship

JJC researched, wrote and edited the article. KH researched and edited the article; SPB, TJ, MM, JW and PS edited and approved the final version.

Acknowledgements:

We would like to acknowledge Dr Adrian Yoong, Consultant Pathologist, Birmingham Women's NHS Foundation Trust, for the personal communication. [We would also like to acknowledge Cambridge University Press and ALSG.org for granting permission for the use of the 'Manual displacement of the uterus' figure.](#)

Comment [JC(GaD1): The disclosure of interests are correct but I have added that the other authors have no competing interests to disclose

1 **[Abstract]**

2

3 **Key content**

4 • Cardiac arrest in pregnancy is rare. Effective management involves the decision to perform a
5 perimortem caesarean section if the gestation is greater than 20 weeks and return of
6 spontaneous circulation does not occur after 4 minutes of effective cardiopulmonary
7 resuscitation.

8 • Delivery should ideally be achieved within 5 minutes of cardiac arrest as this maximises
9 maternal survival and reduces the risk of long-term neurological impairment.

10 • In hospital, the procedure should be undertaken at the site of the cardiac arrest without
11 moving to an operating theatre.

12 • Minimal equipment is required to undertake the procedure. Clinical areas where pregnant
13 women are seen should have a designated 'equipment box'.

14 • Debriefing all personnel is of utmost importance after the acute event.

15

16 **Learning objectives**

17 • To understand why perimortem caesarean section is beneficial to maternal survival.

18 • To appreciate the need for rapid decision making when perimortem caesarean section is
19 required.

20 • To gain practical knowledge of perimortem caesarean section, including the steps to be used
21 when resuscitation is unsuccessful.

22

Perimortem caesarean section

23 Ethical issues

- 24 • To be aware that the primary aim of perimortem caesarean section is to aid maternal
25 survival, not necessarily fetal survival.

26

27 **Keywords:** cardiac arrest / maternal cardiac arrest / perimortem caesarean section /
28 resuscitative hysterotomy

29

30 [Heading 1] Introduction

31 Maternal cardiac arrest is a rare event occurring in approximately 1 in 12 500 pregnancies.¹⁻⁴ The

32 most common causes of cardiac arrest in pregnancy are haemorrhage (45%), amniotic fluid

33 embolism (13%), heart failure (13%), anaesthetic complications (8%) and trauma (3%) (see

34 **Figure 1**).^{1,5,6,7} Because it is so rare, most obstetricians are unlikely to encounter this challenging

35 situation more than once during their career.⁸ When a maternal cardiac arrest does occur, the

36 prospect of performing a perimortem caesarean section (PMCS) is daunting for any healthcare

37 professional, even the most experienced obstetricians. Failure to institute effective life support,

38 which includes performing PMCS in good time, carries devastating consequences for families.⁹ Even

39 when abdominal delivery is expedited in a timely manner, maternal survival remains low (17–

40 59%),^{1,3,4} although fetal survival may be higher (61–80%).^{1,10,11} The key to achieving optimum

41 maternal and fetal survival is the rapidity with which the PMCS can be performed following onset of

42 cardiac arrest.¹²

43 This article explores the rationale for performing PMCS and reviews maternal and fetal outcomes.

44 The authors describe recently proposed alternative terminology and offer practical, step-by-step

Comment [LM1]: AU/ED: Please note the comments I have made on the PPT file re: this figure.

Comment [LW2]: AU: GTG ref moved from no. 13 to no. 7, as it will appear earlier in the text when the ref. is added to the figure 1 legend. References 7-13 renumbered, please check these are OK.

Comment [JC(GaD3)]: The numbering is fine

Perimortem caesarean section

45 advice for performing the procedure. Finally, they will consider how care can be improved with
46 better use of simulation and in-house training.

47

48 **[Heading 1] Perimortem caesarean section – why and when?**

49 In maternal cardiac arrest, the resuscitation algorithm followed is essentially the same as that for
50 nonpregnant women, apart from certain specific anatomical considerations (e.g., manual
51 displacement of the gravid uterus and placement of defibrillator pads).¹³ However, the main
52 difference in the continuing management of cardiac arrest in pregnancy is the critical decision to
53 perform PMCS if cardiopulmonary resuscitation (CPR) fails to result in rapid return of spontaneous
54 circulation (ROSC). The current Royal College of Obstetricians and Gynaecologists' (RCOG) guideline
55 *Maternal Collapse in Pregnancy and Puerperium*⁷ recommends that PMCS should be performed if
56 there is no ROSC after 4 minutes of correctly performed CPR in a woman who is greater than
57 20 weeks of gestation. Delivery of the fetus should ideally be completed 5 minutes after cardiac
58 arrest. The guideline is clear that the procedure is primarily used to assist maternal resuscitation
59 rather than to save the fetus. This has led to the recent recommendation from trauma colleagues to
60 use the alternative term 'resuscitative hysterotomy' (RH).^{14,15} The term PMCS is more familiar in
61 obstetric circles and the authors feel that both terms are acceptable to use in clinical practice.

62 The time targets of 4 and 5 minutes are sourced from a seminal article published by Katz et al. in
63 1986.¹⁰ The case series focused on infant survival, with 42/61 (69%) surviving when PMCS was
64 undertaken within 5 minutes of cardiac arrest. In reviewing a smaller case series, Katz also noted
65 that maternal hypoxic brain injury only occurred in those women who underwent a caesarean
66 delivery that was started 6 minutes or more after cardiac arrest.² Although research evidence for
67 this is not robust, the physiological plausibility is clear: pregnant women are likely to become
68 hypoxic more rapidly than nonpregnant women because of higher oxygen demand.¹⁶ Additionally,

Perimortem caesarean section

69 the gravid uterus impairs venous return with aortocaval compression, reducing cardiac output by up
70 to 60%. Emptying the uterus by delivering the fetus reduces compressive forces on the great vessels
71 (thereby increasing cardiac preload) and reduces oxygen consumption. Lastly, emptying the uterus
72 allows more effective maternal CPR⁷ and potentially more rapid ROSC.

73 The rarity of maternal cardiac arrest and the relatively uncontrolled nature of the clinical situation
74 mean that research evidence is understandably scarce.¹¹ Evidence supporting the practice of PMCS is
75 limited to case reports and case series.

76 Following on from the original recommended targets of 4 and 5 minutes, in 2005 Katz et al.
77 published a literature review of 38 cases of PMCS to confirm the benefits of swift delivery in
78 maternal cardiac arrest.¹² Twenty cases of cardiac arrest were associated with causes where
79 resuscitation was potentially possible. In these cases, 13 (65%) mothers were successfully
80 resuscitated and discharged. Moreover, in 12 out of 18 cases where the haemodynamic status was
81 reported before and after PMCS, delivery of the fetus preceded return of spontaneous circulation.
82 Importantly, this review found that the mothers' condition did not deteriorate because of the
83 procedure. Katz et al. concluded that the data generated from their review supported but fell short
84 of proving the true validity of the 4 and 5-minute rules.

85

86 **[Heading 1] Maternal and fetal outcomes**

87 Several other reviews have collated the outcomes for mothers and neonates following PMCS. The
88 most recent¹⁷ was a systematic review with strict inclusion criteria for selecting primary articles
89 published between 1980 and 2010. The search yielded a total of 80 relevant papers, including a total
90 of 94 patients. The primary outcome measures were maternal and neonatal survival to discharge
91 from hospital; secondary outcome measures were neurological disability and feasibility to undertake
92 PMCS within the advocated timeframe.

Perimortem caesarean section

93 Einav et al.¹⁷ found that PMCS was beneficial in 31.7% of cases and 'not harmful' in any of the
94 identified cases. The review identified that 54.3% (51/94) of mothers survived to hospital discharge,
95 with 78.4% (40/51) surviving with good to moderately impaired neurological outcome. The review
96 also established that if the PMCS was performed within 10 minutes of cardiac arrest, maternal
97 outcomes were more favourable (odds ration [OR] 7.42, $P < 0.05$). Furthermore, neonatal survivors
98 had a shorter mean cardiac arrest-to-delivery time of 14 ± 11 minutes compared to non-survivors
99 (22 ± 13 minutes). Neonatal survival only occurred in cases of maternal cardiac arrest in hospital. The
100 reality is that PMCS is not usually started, nor is the fetus delivered, within the ideal 4 and 5-minute
101 timeframes. Even when these timeframes are breached, maternal or fetal benefits are still possible,
102 with reports of healthy infants being delivered 30 minutes after maternal cardiac arrest.¹⁷ The time
103 can be foreshortened in the labour ward by undertaking the procedure in the delivery room. There is
104 no advantage in transferring the woman to an obstetric theatre because this adds unnecessary
105 delay. For out-of-hospital arrest, it is more difficult to offer definitive advice. Although there are
106 trauma-trained doctors who can potentially perform PMCS outside of hospital, the decision to do so
107 is specific and individualised. In most cases, we expect the woman to be transported to the nearest
108 accident and emergency or trauma department. To minimise further delay on arrival, the most
109 senior obstetrician available should attend and be present in the department when the
110 woman arrives.

111

112 **[Heading 1] Initial resuscitation and perimortem caesarean section**

113 In maternal cardiac arrest, the resuscitation process follows similar algorithms to the nonpregnant
114 woman.¹³ Look for signs of life on arrival (check for breathing and carotid pulse). In the hospital
115 situation, if these are not detected, a call for the cardiac arrest team should be made at the earliest
116 opportunity. At the same time, an emergency call for the obstetric, obstetric anaesthetic and

Perimortem caesarean section

117 neonatal resuscitation teams should be made; specifically, the consultant obstetrician and
118 consultant anaesthetist should be included.

119 Standard basic life support (BLS) should be initiated, using CPR with 30 cardiac compressions to
120 2 ventilation breaths. Important considerations during initial resuscitation are detailed below.

121

122 **[Heading 2] Airway**

123 Standard airway manoeuvres should be performed while looking for signs of life (i.e., head tilt and
124 chin lift, or jaw thrust).¹³ Advanced airway management is usually required and should be
125 anticipated. Difficulties can be encountered, especially in the third trimester. The risk of gastric
126 aspiration is high because of the pressure of the gravid uterus on the stomach and the relative laxity
127 of the cardiac gastric sphincter (a progesterone effect). An experienced anaesthetist should establish
128 an early definitive airway because of the high risk of aspiration during intubation and intubation
129 failure.¹² This usually involves intubation with a cuffed endotracheal tube, taking care not to damage
130 oedematous respiratory tissue. The use of a smaller diameter endotracheal tube should be
131 considered to reduce the risk of failed intubation.¹³

132

133 **[Heading 2] Breathing**

134 Physiological changes occurring in pregnancy lead to higher oxygen consumption and demand.¹⁸
135 Deoxygenation occurs more rapidly in maternal cardiac arrest so supplemental oxygen should be
136 given with a gas flow of 10–15 l min⁻¹.¹⁹ There are some recent concerns suggesting that high flow
137 oxygen supplementation might be detrimental to the fetus in utero and could increase the
138 requirement for neonatal resuscitation.^{20–23} However, in maternal cardiac arrest, the priority is to
139 maximise the chances of maternal survival, thus high flow supplemental oxygen should be
140 administered.²¹ The aim is to achieve arterial oxygen saturation (SaO₂) of 94–98%.

Perimortem caesarean section

141

142 **[Heading 2] Circulation**

143 Cardiac compressions have a direct effect on outcome so should be performed immediately and
144 competently.¹³ However, it is also vital to ensure that the compressive effect of the uterus on the
145 vena cava is alleviated from the start (see manual uterine displacement below).

146 Thirty cardiac compressions (at a rate of 100 per minute) should be performed to every
147 two ventilation breaths until defibrillator pads and the defibrillator are available. Once the patient is
148 intubated, ventilate at a rate of 10 breaths per minute with continuous chest compressions at
149 100 per minute without pausing during ventilation. If the maternal breasts are large or engorged,
150 defibrillator pads may need to be placed on the anterior and posterior precordium to optimise
151 defibrillation energy transfer.

152 Manual uterine displacement is preferred to reduce compression of the inferior vena cava by the
153 gravid uterus (see Figure 2). The uterus should be manually displaced using an 'up, off and over'
154 technique. Maintaining the woman in a fully supine position with the uterus manually displaced
155 makes cardiac compressions easier and more likely to be effective. Alternatively, a left lateral tilt to
156 an angle of at least 15° can be used:^{24,25} slide a solid wedge extending from shoulder to pelvis under
157 the woman to ensure effectiveness.

158 Early vascular access should also be obtained, ideally with two wide-bore (minimum 16 G) cannulae
159 above the level of the diaphragm so that fluids administered are not affected by aortocaval
160 compression.^{7,13} Intraosseous access should be considered in situations where rapid access is
161 required or where intravenous cannulation is difficult. In a maternal cardiac arrest, aggressive fluid
162 resuscitation should be initiated as soon as is practicable. Blood should be requested early and
163 administered according to clinical need.

164

Comment [LM4]: AU/ED: Please note the comments I have made on the PPT file re: this figure.

Comment [JC(GaD5)]: Hi Lisa, We now have permission to use the manual displacement figure from MOET. I have sent the email thread documenting the permission granted. Justin

Perimortem caesarean section

165 **[Heading 1] The decision to proceed with perimortem**

166 **caesarean section**

167 If there is no ROSC after 4 minutes of effectively performed CPR, a clear decision should be made
168 rapidly to start PMCS. The gestational age should be 20 weeks or greater. When gestation is
169 uncertain or where notes or history are not available, the decision to proceed should be made based
170 on a careful, clinical estimation of gestation. A useful working rule is to undertake PMCS/RH if the
171 uterine fundus is at or above the level of the umbilicus. The practical steps to be followed are
172 detailed below. To optimise maternal outcome, note that cardiopulmonary resuscitation should
173 continue uninterrupted during the procedure until either ROSC is confirmed, or until the formal
174 decision to stop resuscitation is made at senior level.

175

176 **[Heading 1] Where should perimortem caesarean section**

177 **be performed?**

178 In the hospital setting, the PMCS can become delayed if the woman is moved to the operating
179 theatre,^{8,17} so the surgery should be performed in the delivery room or in the emergency
180 department. In rare circumstances, PMCS may be considered in the pre-hospital care setting but
181 only when appropriately trained members of medical staff are available.²⁶ It is difficult to give more
182 specific guidance since the decision to undertake PMCS out of hospital or to rapidly transport the
183 patient to hospital is always made on a case-by-case basis. PMCS following cardiorespiratory arrest
184 requires no general anaesthesia and bleeding is initially minimal. However, with successful ROSC,
185 general anaesthesia must be available to allow surgery to be completed.

Perimortem caesarean section

186

187 [Heading 1] Perimortem caesarean section: practical steps

188 [Heading 2] Preparation

189 Full surgical scrub is not required and only basic personal protective equipment should be worn
190 (disposable gloves and apron). Wearing full gowns/masks can cause delays and 'full sterility' is not
191 required. The abdomen should be cleansed where possible, but this should not delay starting the
192 procedure. Minimal equipment is required to perform PMCS: a scalpel and two ligatures or clamps
193 for the umbilical cord. This equipment should be available in hospital departments where obstetric
194 patients are commonly seen because PMCS is usually performed at the site of the cardiac arrest.
195 Although resuscitation guidelines suggest that only a scalpel is required on a cardiac arrest trolley, it
196 is useful for obstetric teams to liaise with relevant departments (e.g., accident and emergency and
197 outpatient departments) to develop a 'PMCS box' similar to the 'eclampsia box' used on many
198 labour wards (see Box 1). This makes additional equipment available with minimal delay. The
199 bladder does not need to be routinely emptied and general anaesthesia is not required to start
200 the procedure.

201

Comment [LM6]: ED/AU: I have changed Table 1 to a Box because it contains only a single-column list.

Comment [JC(GaD7)]: We are happy to have this as a box rather than a table

Perimortem caesarean section

Box 1. Recommended content for a 'perimortem caesarean section (PMCS) emergency box'

Contents is simple and should include:

- Sterile gloves (where not immediately available)
- Disposable apron (where not immediately available)
- Solution for skin preparation/gauze to apply
- Curved no. 10 scalpel blade pre-mounted on disposable handle (or fixed blade scalpel)
- Three disposable cord clamps (or ligatures for hand-tying)
- Sterile intra-abdominal gauze pack/swab (for applying pressure if needed)

Consider:

- Two towels for drying and wrapping baby

202

203 [Heading 2] Abdominal entry

204 For PMCS it is best to make a lower abdominal, vertical midline incision (starting at or just below the
205 umbilicus) because this provides the quickest route of entry into the abdomen to deliver the fetus

206 and offers maximal [access to the abdominal cavity exposure](#).⁶ Some obstetricians and gynaecologists

207 are less familiar with this route of abdominal entry, so a vertical or transverse incision can be used;

208 whichever the clinician feels will provide the most rapid access in their hands.^{7,8} However, if intra-

209 abdominal trauma is a possibility (e.g., in penetrating injury, or suspected hepatic, splenic, bowel or

210 major vessel injury), then a vertical subumbilical, midline incision should always be used. The incision

211 passes sequentially through skin, subcutaneous fat and the fibrous linea alba (in the midline

212 between the rectus abdominis muscles), before finally dividing the parietal peritoneum and entering

Comment [LM8]: AU: Maximal exposure to what? Please clarify

Comment [JC(GaD9)]: Text changed for clarification

Perimortem caesarean section

213 the abdominal cavity. During entry, care should be taken to avoid damaging other organs, though
214 bladder injury is accepted as a particular risk. If this occurs, it can be identified, assessed and
215 repaired at a later stage, assuming successful resuscitation.

216

217 **[Heading 2] Uterine incision**

218 The choice between a lower segment transverse incision and a vertical (classical) incision in the
219 uterus depends on several factors, including the operator's experience and, importantly, the
220 gestation. The type of uterine incision chosen should facilitate the quickest possible delivery of the
221 fetus. If the surgeon is inexperienced in performing caesarean sections, or if the lower segment is
222 narrow (more likely at 20–28 weeks of gestation), then a vertical midline incision should be made in
223 the anterior uterus. This can begin near to the fundus and extend down towards the lower segment.
224 Try to avoid injury to the fundus of the bladder, which can reach the upper margin of the lower
225 segment. The uterine upper segment is relatively thick (3–4 cm) and superficial injury to the fetus is
226 a risk during rapid entry. Use scissors or a scalpel to enlarge the vertical uterine incision in both
227 caudal and cephalic directions. Once most of the muscle fibres have been cut, it can be helpful to
228 stretch the uterine incision with the fingers to provide a wide, open access point that allows
229 easy delivery.

230 If the lower segment is reasonably well formed (which it might not be until at least 28 weeks of
231 gestation) or the surgeon is familiar with caesarean sections, then a transverse lower segment
232 incision may be considered. However, this can cause some delay because the bladder must be
233 mobilised from the lower segment. The cord should be double-clamped or ligated and promptly
234 divided between the clamps/ligatures (use a skin scalpel if scissors are not available). Be aware that
235 if the baby is alive, active neonatal resuscitation is required.

Perimortem caesarean section

236

237 **[Heading 2] Managing the placenta**

238 Once the baby is delivered, the placenta can be delivered or left in situ, but maternal resuscitation
239 should continue. Management is dictated by the subsequent effectiveness of continuing
240 resuscitation. If resuscitation is successful, increasing uterine tone will cause placental separation
241 and the placenta can be delivered. Be prepared for bleeding and ensure that uterine tone is
242 appropriate and maintained.

243

244 **[Heading 2] Management when resuscitation is successful**

245 With ROSC, bleeding can arise from an atonic uterus (requiring appropriate uterotonic medication)
246 and/or from the edges of uterine incision. The latter can be initially managed by applying local
247 pressure, using a handheld sterile pack or large gauze swabs if available. General anaesthesia should
248 be administered and the woman transferred as soon as possible to an operating theatre for formal
249 exploration and closure. Appropriate broad-spectrum intravenous antibiotics should be given and
250 duration of treatment clearly documented.

251 The uterus and abdomen should be anatomically closed to achieve adequate haemostasis. Lower
252 segment incisions can be closed in a standard way, but upper segment incisions usually require
253 three layers of sutures to ensure closure and to secure haemostasis. Number 1-sized suture material
254 should be used (braided polyglactin or similar) to reduce the risk of tearing through the uterine
255 muscle. It is vital to have an assistant on hand during closure so they can hold the thick walls of the
256 upper uterine segment together while individual sutures are inserted and tied. The first layer should
257 be closed using interrupted figure-of-eight or 'Z' stitches because these are more haemostatic.
258 Depending on factors including the amount of bleeding and tissue friability, subsequent layers might
259 also require interrupted sutures. Adequate time should be allowed for uterine closure to ensure that
260 uterine perfusion and blood pressure have normalised to ascertain haemostasis. However, if

Perimortem caesarean section

261 bleeding continues, abdominal and/or pelvic packing might be required.^{13,27} A large-bore, non-
262 suction tube drain should be left in place. If a pack is left in situ, the abdomen should be partially
263 closed with only a few skin sutures – a return to theatre is expected within 24 hours to remove the
264 pack and undertake definitive closure. After surgery, immediate and continuing care usually takes
265 place on an intensive critical care unit. The final destination depends on the cause of cardiac arrest
266 and the woman's overall clinical state. In all circumstances, senior medical staff should be involved in
267 a multidisciplinary team discussion to ensure an appropriate decision is made.^{1,7,28,29}

268

269 **[Heading 2] Management when resuscitation is unsuccessful**

270 After the uterus is emptied, resuscitation efforts should continue until the clinical situation dictates a
271 decision to stop. This decision should be made by the attending senior consultant team (made up of
272 obstetricians, anaesthetists, accident and emergency staff, etc.), together with the cardiac arrest
273 team,⁷ and be clearly stated to ensure that all team members agree. The coroner (or relevant legal
274 entity) should be informed of the death at the earliest opportunity. If a coroner's postmortem
275 examination is required to delineate the underlying cause (or causes) of death, medical devices such
276 as vascular catheters and endotracheal tubes should be left in situ.² Although in England there is no
277 formal national guidance about management of the equipment used or in place at the time of death,
278 the recommendations below should be adhered to;³⁰ these facilitate any postmortem required by
279 the coroner, while remaining sensitive to the family:

- 280 1. All intravenous access ports, lines and intubation equipment in place at the time of
281 declaration of death should be secured and left in situ.
- 282 2. The placenta should not be removed if it was in place at the time of death, and if the uterus
283 was open it should be left unsutured. Preferably, an open abdomen should be left as such
284 and covered with a dressing. However, out of consideration for the feelings of family

Perimortem caesarean section

285 members, it might be appropriate to close the skin edges of a large incision with a minimal
286 number of simple sutures before covering the wound with a dressing.

287 3. The state of the abdomen at the time of death should be carefully recorded in the medical
288 records (e.g., whether the abdomen was open, the placenta was in place, the uterus was
289 open or repaired), in addition to whether sutures used to close the abdomen were placed
290 after death.

291

292 [Heading 1] After care

293 After PMCS, appropriate neonatal care and family support is vital, whatever the outcome. Keeping
294 contemporaneous medical notes can be difficult, but all staff should ensure that comprehensive
295 notes are added to the medical/nursing records as soon as possible after the event.^{31,32} Entries
296 should be signed, timed and dated appropriately. As well as accurate documentation, a completed
297 critical incident report is required and, in the event of a maternal death, the coroner must be
298 informed. The importance of confidential enquiries should not be overlooked and appropriate
299 information should be forwarded to the relevant bodies.^{5,6}

300 The distress caused by a maternal cardiac arrest must not be underestimated. For the family,
301 unsuccessful resuscitation means the loss of a wife, daughter or mother, and possibly a much-
302 wanted baby too. Even if resuscitation is successful, for both the family and the members of staff
303 involved in the patient's care, the emotional trauma from such a dramatic event can have significant
304 emotional consequences.^{15,19,33,34} Primary care and supporting community services should be directly
305 informed as soon as possible after the event, whatever the outcome.

306 Both relatives and staff members should be offered a thorough debrief with detailed exploration and
307 discussion of the events. These are often held separately for staff and relatives, but later a joint
308 meeting may be requested. The debrief can involve members of the multidisciplinary team including

Comment [LM10]: AU: I have deleted this sentence as it says almost the same thing as the next two sentences.

Comment [JC(GaD11)]: That's fine with us

Perimortem caesarean section

309 paramedics and staff from accident and emergency, theatre, critical care and maternity
310 departments. This must be undertaken at an appropriate time, in a suitable place.^{15,19} It is useful to
311 keep family members abreast of the events as they evolve, particularly in the weeks leading up to
312 their planned formal review or full debrief. Additional pastoral support and counselling should be
313 provided to relatives, staff and other patients who have witnessed the events.

314

315 **[Heading 1] Improving care**

316 The medical literature to help direct high-quality care in the management of maternal cardiac arrest
317 and PMCS remains sparse.³⁵ Practice will improve as further knowledge is accumulated from case
318 reports, small series and reviews, and the use of confidential enquiries such as MBRRACE-UK
319 (Mothers and Babies: Reducing Risk through Audits and Confidential Enquiries across the UK).^{5,6,36,37}
320 Clinicians should continue to report these rare events and, in the UK, the UKOSS reporting system
321 is exemplary.³⁸

322 Simulation courses such as the PRactical Obstetric Multi-Professional Training (PROMPT)³⁹ course
323 and Managing Obstetric Emergencies and Trauma (MOET)¹³ can help maternity teams to improve
324 technical, communication, decision-making and team-working skills. Simulation training improves
325 clinicians' knowledge and confidence^{3,9} and can facilitate rapid and effective action in maternal
326 cardiac arrest. For example, implementing simulation-based training in the management of a
327 maternal cardiac arrest led to quicker initiation of cardiopulmonary resuscitation and PMCS.⁹
328 Additionally, competent team performance in the management of obstetric emergencies (such as
329 the management of maternal cardiac arrest) is not a function of the knowledge and skills of
330 individuals but is instead associated with the skills of the team as a whole, including team behaviours
331 and leadership skills. Simulation training develops these team-orientated skills, including allocating
332 tasks to specific team members who know and understand their individual roles.^{40,41} In the authors'

Perimortem caesarean section

333 opinion, multidisciplinary team training in cardiorespiratory arrest leading to PMCS should be a
334 mandatory 'hot drill' that is practiced regularly on all delivery suites.

335 [Heading 1] Conclusion

336 Obstetricians will rarely need to perform a PMCS; colleagues in accident and emergency will
337 encounter this clinical situation even more rarely but may be called upon to perform a PMCS in a
338 critical trauma scenario. ~~indeed, some will never come across one, especially our colleagues in~~
339 accident and emergency or trauma situations, who might be called upon to make the critical, acute
340 decision to proceed. For any individual in this rare situation, the take-home message is to focus on
341 the need for rapid action to maximise the chance of maternal survival. Therefore, the critical step is
342 to make the decision to proceed with a PMCS. Fetal survival depends on many factors including
343 gestation, but is a secondary issue and should not be the prime driver for deciding whether or not to
344 perform a PMCS.

345 Realistically, the only situation in which PMCS is likely to be achieved within the recommended time
346 frame of 4–5 minutes is when maternal cardiac arrest occurs in the delivery suite. When the woman
347 is in transit by ambulance, the most senior obstetrician available should be urgently called to be
348 present when the woman arrives at the accident and emergency department to minimise delay in
349 proceeding to PMCS. Maternal survival rate falls rapidly with increasing time from the initial arrest.
350 However, if resuscitation attempts continue, we recommend that PMCS should still be performed
351 even when the delay is 30 minutes or more. In hospital situations, PMCS should be performed at the
352 site of cardiac arrest.

353 Rapid and effective action can be improved through multidisciplinary team training. It is useful for
354 units to consider joint training drills with colleagues in accident and emergency departments.
355 Obstetricians should help to develop joint guidelines that cross departmental boundaries and ensure
356 that, for this rare event, all staff know who to call and when. A 'PMCS box' containing the basic

Comment [LW12]: AU: this appears to say that those working in A&E are especially unlikely to encounter PMCS – just to clarify, is this correct?

Comment [JC(GaD13): I have changed the text to improve clarity

Perimortem caesarean section

357 equipment needed is a useful adjunct. The PMCS procedure is relatively simple and the steps
358 required have been described.

359 As with all critical obstetric emergencies, detailed documentation is vital. All steps of the acute
360 intervention should be specifically timed and recorded, and health records completed as soon as
361 possible after the intervention. A member of the acute team can be allocated to keep
362 contemporaneous notes and timings throughout the resuscitation period.

363 High-quality support and care should continue after the acute event, ensuring prompt
364 communication with primary care colleagues and community-based services. A comprehensive and
365 sensitive debriefing should be undertaken, with formal counselling and support to follow when
366 required. Units may wish to consider a joint debriefing/review, which can include both the staff
367 involved in the patient's care and the patient and/or their family members.

368

369 **[Heading 1] References**

- 370 1 Rose C, Arij Faksh D, Traynor K, Cabrera D, Arendt KW, Brost BC. Challenging the 4- to 5-
371 minute rule: from perimortem cesarean section to resuscitative hysterotomy. *Am J Obstet*
372 *Gynecol* 2015;**213**:653–6.
- 373 2 Katz VL. Perimortem cesarean delivery: its role in maternal mortality. *Semin Perinatol*
374 2012;**36**:68–72.
- 375 3 Dijkman A, Huisman CMA, Smit M, Schutte JM, Zwart JJ, van Roosmalen JJ, et al. Cardiac
376 arrest in pregnancy: Increasing use of perimortem caesarean section due to emergency skills
377 training? *BJOG* 2010;**117**:282–7.
- 378 4 Mhyre J, Tsen L, S E, Einav S, Kuklina EV, Leffert LR, Bateman BT. Cardiac arrest during
379 hospitalization for delivery in the United States, 1998–2011. *Anesthesiology* 2014;**120**:810–8.

Perimortem caesarean section

- 380 5 Kemp B, Knight M. Maternal mortality in the UK: an update. *Obstet Gynaecol Reprod Med*
381 2016;**26**:26–8.
- 382 6 Knight M, Kenyon S, Brocklehurst P, Neilson J, Shakespeare J, Kurinczuk JJ, editors. *Saving*
383 *Lives, Improving Mothers' Care. Surveillance of maternal deaths in the UK 2012–14 and*
384 *lessons learned to inform future maternity care from the UK and Ireland Confidential Enquiries*
385 *into Maternal Deaths and Morbidity 2009–2012*. Oxford: National Perinatal Epidemiology
386 Unit, University of Oxford; 2014 [[https://www.npeu.ox.ac.uk/downloads/files/mbrbrace-](https://www.npeu.ox.ac.uk/downloads/files/mbrbrace-uk/reports/Saving%20Lives%20Improving%20Mothers%20Care%20report%202014%20Full.pdf)
387 [uk/reports/Saving%20Lives%20Improving%20Mothers%20Care%20report%202014%20Full.p](https://www.npeu.ox.ac.uk/downloads/files/mbrbrace-uk/reports/Saving%20Lives%20Improving%20Mothers%20Care%20report%202014%20Full.pdf)
388 [df](https://www.npeu.ox.ac.uk/downloads/files/mbrbrace-uk/reports/Saving%20Lives%20Improving%20Mothers%20Care%20report%202014%20Full.pdf)].
- 389 7 Royal College of Obstetricians and Gynaecologists. *Maternal collapse in pregnancy and*
390 *puerperium. Green-top Guideline No. 56*. London: RCOG; 2011.
- 391 8 Drukker L, Hants Y, Sharon E, Seia HY, Grisaru-Granovsky S. Perimortem cesarean section for
392 maternal and fetal salvage: concise review and protocol. *Acta Obstet Gynecol Scand*
393 2014;**93**:965–72.
- 394 9 Fisher N, Eisen LA, Bayya JV, Dulu A, Bernstein PS, Merkatz IR, et al. Improved performance of
395 maternal-fetal medicine staff after maternal cardiac arrest simulation-based training. *Am J*
396 *Obstet Gynecol* 2011;**205**:239.e1–5.
- 397 10 Katz V, Dotters D, Droegemueller W. Per-mortem cesarean delivery. *Obstet Gynecol*
398 1986;**68**:571–6.
- 399 11 Baghirzada L, Balki M. Maternal cardiac arrest in a tertiary care centre during 1989–2011: a
400 case series. *Can J Anesth* 2013;**60**:1077–84.
- 401 12 Katz V, Balderston K, Defreest M. Perimortem cesarean delivery: were our assumptions
402 correct? *Am J Obstet Gynecol* 2005;**192**:1916–21.

Comment [LM14]: AU: I have replaced the URL here with the direct link to the report rather than the homepage. Please check this is the correct document.

Comment [JC(GaD15)]: This is the correct document

Perimortem caesarean section

- 403 13 Paterson-Brown S, Howell C, editors. *The MOET course manual: managing obstetric*
404 *emergencies and trauma*. 3rd ed. Cambridge: Cambridge University Press; 2014.
- 405 13
- 406 14 Lipman SS, Cohen S, Mhyre J, Carvalho B, Einav S, Arafeh J, *et al*. Challenging the 4- to 5-
407 minute rule: From perimortem cesarean to resuscitative hysterotomy. *Am J Obstet Gynecol*
408 2016;**215**:129–31.
- 409 15 Jeejeebhoy FM, Morrison LJ. Maternal cardiac arrest: a practical and comprehensive review.
410 *Emerg Med Int* 2013;**2013**:274814.
- 411 16 Awe RJ, Nicotra MB NT. Arterial oxygenation and alveolar-arterial gradients in term
412 pregnancy. *Obs Gynecol* 1979;**53**:182–6.
- 413 17 Einav S, Kaufman N, Sela HY. Maternal cardiac arrest and perimortem caesarean delivery:
414 evidence or expert-based? *Resuscitation* 2012;**83**:1191–200.
- 415 18 Quinn AC, Milne D, Columb M, Gorton H, Knight M. Failed tracheal intubation in obstetric
416 anaesthesia: 2 yr national case-control study in the UK. *Br J Anaesth* 2013;**110**:74–80.
- 417 19 Jones R, Baird SM, Thurman S, Gaskin IM. Maternal cardiac arrest: an overview. *J Perinat*
418 *Neonatal Nurs* 2012;**26**:117–23.
- 419 20 Chesnutt AN. Physiology of normal pregnancy. *Crit Care Clin* 2004;**20**:609–15.
- 420 21 O’Driscoll BR, Howard LS, Bucknall C, Welham SA, Davison AG, British Thoracic Society. British
421 Thoracic Society emergency oxygen audits. *Thorax* 2011;**66**:734–5.
- 422 22 Kleinman ME, Chameides L, Schexnayder SM, Samson RA, Hazinski MF, Atkins DL, *et al*. Part
423 14: pediatric advanced life support: 2010 American Heart Association Guidelines for
424 Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*

Perimortem caesarean section

- 425 2010;**122**:S876–908.
- 426 23 Nesterenko TH, Acun C, Mohamed MA, Mohamed AN, Karcher D, Larsen J Jr, et al. Is it a safe
427 practice to administer oxygen during uncomplicated delivery: a randomized controlled trial?
428 *Early Hum Dev* 2012;**88**:677–81.
- 429 24 Hunter S, Robson SC. Adaptation of the maternal heart in pregnancy. *Br Heart J* 1992;**68**:540–
430 3.
- 431 25 Lee SWY, Khaw KS, Ngan Kee WD, Leung TY, Critchley LA. Haemodynamic effects from
432 aortocaval compression at different angles of lateral tilt in non-labouring term pregnant
433 women. *Br J Anaesth* 2012;**109**:950–6.
- 434 26 Battaloglu E, McDonnell D, Chu J, Lecky F, Porter K. Epidemiology and outcomes of pregnancy
435 and obstetric complications in trauma in the United Kingdom. *Injury* 2016;**47**:184–7.
- 436 27 Guven S, Yazar A, Yakut K, Aydogan H, Erguven M, Avci E. Postmortem cesarean: report of our
437 successful neonatal outcomes after severe trauma during pregnancy and review of the
438 literature. *J Matern Fetal Neonatal Med* 2012;**25**:1102–4.
- 439 28 Lopez-Zeno JA, Carlo WA, O’Grady JP, Fanaroff AA. Infant survival following delayed
440 postmortem cesarean delivery. *Obs Gynecol* 1990;**76**:991–2.
- 441 29 Ural UM. Postmortem cesarean section: a case report. *J Clin Anal Med* 2013;**4**.
- 442 30. Yoong AK, personal communication.
- 443 31 Pattinson R. Near miss audit in obstetrics. *Best Pract Res Clin Obstet Gynaecol* 2009;**23**:285–6.
- 444 32 Mustafa R, Hashmi H. Near-miss obstetrical events and maternal deaths. *J Coll Physicians*
445 *Surg Pakistan* 2009;**19**:781–5.
- 446 33 Catling-Paull C, McDonnell N, Moores A, Homer CS. Maternal mortality in Australia: learning

Comment [LM16]: ED/AU: I have added this personal communication to the list of references as per the journal's preferred style and renumbered the following references accordingly.

Comment [JC(GaD17)]: That's fine with me

Perimortem caesarean section

- 447 from maternal cardiac arrest. *Nurs Heal Sci* 2011;**13**:10–5.
- 448 34 Jeejeebhoy FM, Zelop CM, Windrim R, Carvalho JC, Dorian P, Morrison LJ. Management of
449 cardiac arrest in pregnancy: a systematic review. *Resuscitation* 2011;**82**:801–9.
- 450 35 King S, Gabbot D. Maternal cardiac arrest – rarely occurs, rarely researched. *Resuscitation*
451 2011;**82**:795–6.
- 452 36 Kurinczuk JJ, Draper ES, Field DJ, Bevan C, Brocklehurst P, Gray R, *et al*. Experiences with
453 maternal and perinatal death reviews in the UK – the MBRRACE-UK programme. *BJOG*
454 2014;**121**:41–6.
- 455 37 Field D. MBRRACE-UK and the UK-wide national Maternal, Newborn and Infant Clinical
456 Outcome Review Programme – an update. *Infant* 2013;**9**:119–20.
- 457 38 O'Connor M, Nair M, Kurinczuk JJ, Knight M. UKOSS Annual Report 2016. Oxford: National
458 Perinatal Epidemiology Unit; 2016.
459 [[https://www.npeu.ox.ac.uk/downloads/files/ukoss/annual-](https://www.npeu.ox.ac.uk/downloads/files/ukoss/annual-reports/UKOSS%20Annual%20Report%202016.pdf)
460 [reports/UKOSS%20Annual%20Report%202016.pdf](https://www.npeu.ox.ac.uk/downloads/files/ukoss/annual-reports/UKOSS%20Annual%20Report%202016.pdf)].
- 461 39 PROMPT Maternity Foundation. *PROMPT Course Manual*. 2nd ed. Cambridge: Cambridge
462 University Press; 2012.
- 463 40 Smith A, Edwards S, Siassakos D. Effective team training to improve outcomes in maternal
464 collapse and perimortem caesarean section. *Resuscitation* 2012;**83**:1183–4.
- 465 41 Siassakos D, Fox R, Crofts JF, Hunt LP, Winter C, Draycott TJ. The management of a simulated
466 emergency: better teamwork, better performance. *Resuscitation* 2011;**82**:203–6.

467

468 **Figure legends:**

Comment [LM18]: AU: I have updated this reference – the original URL pointed to an information page about UKOSS, yet the reference seemed to be citing the annual report. Please check this is correct and amend as necessary.

Comment [JC(GaD19): This new URL is good

Perimortem caesarean section

469 **Figure 1.** Causes of maternal collapse. Reproduced with the permission of the Royal College of

470 Obstetricians and Gynaecologists.¹³

471 **Figure 2.** Manual displacement of the uterus.

Figure 1. Causes of maternal collapse.

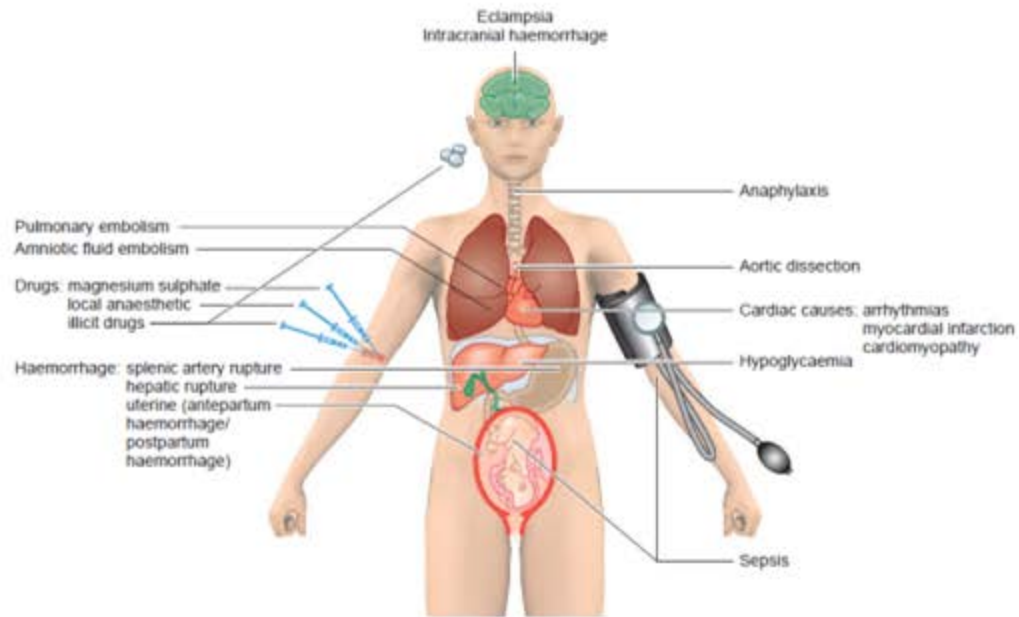


Figure 2. Manual displacement of the uterus.



Box 1. Recommended content for a 'PMCS emergency box'

Recommended content for a 'PMCS' emergency box
<p>Content is simple & should include:</p> <ul style="list-style-type: none">• Sterile gloves (where not immediately available)• Disposable apron (where not immediately available)• Solution for skin preparation / gauze to apply• Curved No. 10 scalpel blade pre-mounted on disposable handle (or fixed blade scalpel)• x3 disposable cord clamps (or ligatures for hand-tying)• Sterile intra-abdominal gauze pack/swab (for applying pressure if needed)
<p>Consider:</p> <ul style="list-style-type: none">• x2 towels for drying & wrapping baby