Liver lacerations as a complication of CPR during pregnancy

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Keywords: Obstetrics, Pregnancy, Cardiopulmonary Resuscitation, Cardiac Arrest, Complications (CPR), Liver Laceration, Liver Injury

Abstract

Aim: Cardiac arrest in peripartum patients is a rare but devastating event; reported rates in the literature range from 0.019% to 0.0085%. In the general population, a well-described complication of cardiopulmonary resuscitation (CPR), liver laceration and injury, is reported at a rate of between 0.5-2.9% after CPR. Liver laceration rate among peripartum patients receiving CPR has not been well-studied. We sought to find the rate of liver lacerations in the peripartum population associated with CPR, with the hypothesis that the rate would be higher than in the general population.

Methods: We identified pregnancies complicated by cardiac arrest by performing a retrospective medical record review from 2011-2016 at a single tertiary referral hospital. We then compared the rate of liver lacerations in this group to the rate in the general population as found in the literature.

Results: Eleven of 9408 women in the peripartum period suffered cardiac arrest. Return of spontaneous circulation occurred in seven of eleven (64%) women. Three of these seven women suffered clinically significant liver laceration (43%). Overall mortality rate among women suffering cardiac arrest was 82% (9/11).Even after return of spontaneous circulation, the mortality rate was 72%(5/7) including two of three women suffering liver laceration.

Conclusions: Based on a small retrospective study, liver lacerations requiring intervention occurred in 43% of gravidas patients that survived CPR, and is significantly higher than published rates (0.6-2.1%) for the general patient population. Further studies are indicated to determine if this rate of liver injury associated with peripartum CPR.

Introduction

Maternal cardiac arrest is a rare, frightening and devastating event, often resulting in the demise of the mother, fetus/neonate or both. The most common cause of maternal cardiac arrest is haemorrhage, accounting for up to 40% of all cases.[1-3] The reported rate of CPR among the peripartum population within developed countries ranges from 1:53,260 (0.019%) to 1:11,749 (0.0085%).[1-5]

Cardiopulmonary resuscitation (CPR) is an important intervention that has improved survival after cardiac arrest since being described almost 60 years ago.[6] Due to the physiologic changes that occur in pregnancy, guidelines for BLS/ACLS in the pregnant patient have been modified; for example, closed chest compressions are performed while manually displacing the gravid uterus to the left to alleviate compression of the vena cava and chest compressions are focused slightly higher on the sternum. However, exact hand placement is not specified and it is unknown if most responders are aware of this alteration.[7-12] In addition, in the absence of a return of spontaneous circulation (ROSC) within four minutes, immediate perimortem cesarean delivery (ameliorating caval compression) is indicated to achieve optimal maternal outcome.[4,7,11,13-15]

Though the liver is often congested due to a lack of venous return during cardiac arrest, the rate of liver injury in the general population after CPR is low.[16-18] In pregnancy, hepatic congestion in addition to other physiologic changes are reported. [7,19-22] While an enlarged liver in pregnancy is only reported in patient with prior liver disease[19,20], a more palpable liver immediately postpartum has been reported[22].

We hypothesized that chest compressions performed on pregnant and "early postpartum" patients are associated with an increased rate of liver lacerations during CPR as compared to the general population. Our primary objective was to determine the rate of liver laceration as a complication of CPR in pregnancy.

Methods

Using a protocol approved by our institutional review board (HP-0071605), a retrospective case review was performed at the University of Maryland Medical Center (UMMC) from 2011-2016. Cases of CPR performed on peripartum women, including transfers from other

hospitals, were identified both by inspection of obstetric, anesthesiology, and trauma databases and by query of UMMC discharge records, using codes: arrest (475.5) and pregnancy (v22.1). Patient demographics and details surrounding each cardiac arrest event including post-CPR complications were then gathered. Inclusion criteria were pregnancy (from 20 weeks' gestation to one year postpartum), suffering a cardiac arrest and CPR. Exclusion criteria included known prior liver injury or disease. Records were reviewed to determine liver injury after CPR.

The total number of peripartum women with cardiac arrest who receive CPR was divided by the total number of deliveries at UMMC from 2011-2016 to determine the period prevalence of CPR in pregnancy. The number of women with liver injury associated with CPR in pregnancy was divided by the previously determined total number of pregnancies complicated by cardiac arrest and CPR to determine the period prevalence of liver injury associated with CPR in pregnancy. A thorough literature review was performed to identify the rates of CPR as well as any published rates of liver injury from CPR both in the general population and in pregnant women.

Results

Including transfers to UMMC during 2011-2016, eleven cases of cardiac arrest and CPR in peripartum women were identified out of 9,408 deliveries at UMMC. All eleven women met inclusion criteria (Table 1). Return of spontaneous circulation occurred in 7 of the patients (64%). Overall mortality was 82%. The period prevalence of cardiac arrest among all deliveries at UMMC during this six-year span was 0.12% (1:855). Liver lacerations occurred in three of the eleven women. The period prevalence of liver injury associated with CPR in pregnant women at UMMC was 27%, and was 43% amongst survivors of CPR. All three of these women suffered clinically significant liver lacerations, only one survived (Table 2).

Case 1

A 34-year-old G6P3, presented to Labor & Delivery at 31 weeks' gestation with abdominal pain and leakage of fluid. She had a history of diabetes mellitus (type 1), hypertension and chronic kidney disease. Her calculated BMI was 25 m^2/kg. She was diagnosed with preterm premature rupture of membranes. She was started on magnesium sulfate and steroids were administered. Shortly after administration of the magnesium, she became unresponsive and it

was thought she had a seizure. Immediately following emergent delivery by cesarean section, the patient experienced cardiopulmonary arrest and ACLS was started. ROSC occurred fifteen minutes later. Massive abdominal haemorrhage continued after closure of the uterine incision; a hysterectomy was performed. She continued in shock despite massive transfusion and intravenous infusion of vasopressors. Further abdominal exploration revealed liver injury, including a: large (right lobe) subcapsular hematoma; laceration adjacent to the gallbladder; and, separate left infra-lobar laceration. Her postoperative course deteriorated further in the intensive care unit (ICU). Despite heroic measures, she remained unresponsive with evidence of brain death, expiring after termination of further resuscitative efforts.

Case 2

A 35-year-old G3P2 presented to an outside hospital (OSH) at 38 weeks' gestation with confusion, agitation, tachypnea and cyanosis. She offered no significant medical history. Her calculated BMI was 21 m^2/kg. Diagnosed with a pulmonary embolism, tPA (50mg) was intravenously infused. Manifesting maternal shock and with a category III fetal heart rate pattern displayed on the electronic fetal heart rate monitor, she underwent abdominal delivery. In the immediate postpartum period, she was transferred to UMMC for veno-arterial ECMO. During cannulation of the right femoral artery, she lapsed into cardiac arrest. ACLS was initiated and ROSC was noted ten minutes later. A hysterectomy was performed for massive vaginal hemorrhage. Further abdominal exploration revealed liver injury including a ruptured subcapsular hematoma and a large infra-lobar (right) laceration. Echocardiography revealed a large left ventricular thrombus. Resuscitation, including hepatic artery embolization, was continued but unsuccessful and the patient expired the same day.

Case 3

A 24-year-old G3P2 presented to an OSH at 40 weeks' gestation in active labor. She had a history of uterine fibroids. Her calculated BMI was 28 m^2/kg. She underwent vacuum-assisted vaginal delivery. Subsequent massive (vaginal) haemorrhage, with clinical and laboratory signs of coagulopathy, led to hysterectomy. In the ICU, she suffered cardiac arrest. ACLS was performed; ROSC occurred. With continued clinical/laboratory signs of abdominal hemorrhage, the patient returned to the OR. Laparotomy revealed hepatic injury including a large linear infra-lobar (right) laceration and a large subcapsular hematoma of the dome. She remained

haemodynamically unstable even after embolization of the distal right hepatic artery. She was transferred to UMMC. She was stabilized and her coagulopathy corrected. Damage-control exploration of her abdomen was performed followed ten days later by a delayed primary closure. The patient recovered and continues to do well.

Discussion

Added to the normally tumultuous scene occurring at any cardiac arrest, having a pregnant patient who requires CPR heightens anxiety for all healthcare providers involved. Furthermore, the scenario can become more complicated if they must prepare for a perimortem caesarean section (PMCS) if there is no return of spontaneous circulation within an ideal goal of four minutes.[8-11,13-15]

The rate of CPR in the peripartum population of developed countries varies, including: The Netherlands (0.0019%)[4]; Scotland (0.002%)[5]; United Kingdom (0.0028-0.0063%)[3]; Canada (0.008%)[2]; and, the United States (0.085%).[1] A study of maternal cardiac arrest in a Canadian tertiary care center reported a rate of 1:24,883 (0.004%), but excluded postpartum circulatory arrests.[23]

The peripartum CPR rate seen at our institution is almost 15-fold (0.12% vs. 0.0085%) higher as compared to published rates.[1] A factor likely skewing our results is that as a tertiary care referral center, many of our obstetric patients are transferred from other hospitals where they have already been diagnosed with significant complications of pregnancy. This is in additiong to our hospitals' own high-acuity, high-risk obstetric patient population. Indeed, five of the 11 patients in this report were transferred to our facility (Table 1).

Liver injury after CPR in peripartum patients has not been well-studied.[24,25] We could not find any comparisons of injury rates between women in the peripartum period undergoing CPR and those reported in the general population. Among the general population, reports on complications associated with CPR reveal the majority of complications are non-life threatening (e.g., rib fractures), while more severe complications (e.g., liver injury) are rare. In 1987, Krischer, *et al*., found the incidence of liver rupture to be 2.1%, in addition to "other liver injuries" at 0.8%, putting the total incidence of liver injury at 2.9%.[17] A more recent study put

the overall rate at 0.6%, with an even lower rate of 0.5% in women.[16] Published case reports of liver injury after CPR indicate that the complication was typically significant, resulting in hemorrhage and death.[18,26,27] Two other case reports are reported of liver injury during CPR in pregnancy.[21,28] Outside of pregnancy, a few case reports have purposed the reasoning for clinically significant liver injury is secondary to coagulopathy.[16,27,29,30] or untrained personnel.[31] Our rate of clinically significant liver injury associated with CPR in pregnancy (27%) is likewise much higher than the published rates of liver laceration associated with CPR in the general population (0.6-2.1%). Two of the three patients were coagulopathic prior to arrest and this may have played a significant role in the mechanism of injury to the liver. .

We can proffer an explanation for this increased rate of liver injury associated with CPR, partially due to the physiologic changes in pregnancy. One study found no significant rostral displacement of the heart in pregnancy; challenging the dogma of pregnancy-associated elevation of the diaphragm.[32]This suggests the diaphragm acts as a "rigid wall" enclosing the abdominal organs. An enlarged uterus during pregnancy and even in the postpartum period results in less abdominal capacity and possibily physiologic compression of the liver capsule. In addition, increased intravascular volume and hepatic congestion as noted by other authors[7,20,22,33,34] could potentially increase hepatic susceptibility to injury. More work, however, is needed to confirm this increased incidence of clinically important liver lacerations in peripartum patients, and to evaluate possible etiologies for this difference.

The major limitation of this study is that it is a retrospective case series of a rare event at a single institution. Additionally, we are unable to determine whether the rate of liver injury after CPR is specific to our high-acuity hospital as we did not calculate the period prevalence in non-pregnant patients. The survival to discharge rates for all patients receiving CPR at our institution is 25.0% which is similar to the findings of our study. A recent study, however, demonstrates that CPR in pregnancy has a better prognosis than non-pregnant individuals.[35,36] Due to the limitations of record review, we were often unable to find details of the CPR performed, including hand position during closed chest massage or if any bedside alterations were made to resuscitation methods promulgated in the AHA guidelines for peripartum CPR. We were unable to account for confounding variables associated with coagulopathy in critically-ill gravidae, such as Thrombotic Thrombocytopenia Purpura (TTP), Disseminated Intravascular Coagulation

(DIC), or pre-eclampsia. All three patients who suffered liver lacerations developed DIC, two prior to CPR and the other after successful resuscitation.

More accurate rates of both peripartum CPR and associated liver lacerations could be revealed in a future study including data from multiple states- or nation-wide hospitals as well as for a period longer than six years. This would allow for comparison of rates in age-matched and non-pregnant women. If there is a pre-disposition to liver laceration in pregnant women then nation-wide results might validate or support change in current guidelines for CPR in peripartum women. Thought should be given to performing either surgical exploration, abdominal ultrasound to evaluate for intra-abdominal free fluid, or CT evaluation of the upper abdomen in all gravidae who remain haemodynamically unstable after cardiopulmonary resuscitation. A shorter time-to-diagnosis of liver injury might increase the efficacy of available surgical and non-surgical interventions to prevent complications of massive haemorrhage, transfusion and shock.

Conclusions

Based on this small retrospective case series at our tertiary care, obstetric and trauma referral hospital, liver lacerations requiring intervention occurred in 43% of gravidae patients who survived CPR, and is significantly higher than published rates (0.6-2.1%) for the general patient population. Further studies are indicated to determine if this rate of liver injury associated with peripartum CPR is generalizable beyond our hospital. We believe that recognition of its increased prevalence, and early consideration for the diagnosis allows for rapid treatment of this life threatening complication, and may allow for an improvement in outcomes for these unfortunate patients.

Conflicts of interest: None.

Individual Contributions of the Authors:

Timothy Cox: Conceived, primarily researched and prepared data, wrote and edited the final manuscript.

Sarah Crimmins: Primarily conceived, wrote and edited the final manuscript

Allison Shannon: Researched and edited the final manuscript

Kristin Atkins: Conceived and edited the final manuscript

Ronald Tesoriero: Facilitated research and edited the final manuscript

Andrew Malinow: Facilitated research, wrote and edited the final manuscript

References

1 Mhyre, J. M. *et al.* Cardiac arrest during hospitalization for delivery in the United States, 1998-2011. *Anesthesiology* **120**, 810-818, doi:10.1097/aln.0000000000000159 (2014).

2 Balki, M., Liu, S., Leon, J. A. & Baghirzada, L. Epidemiology of Cardiac Arrest During Hospitalization for Delivery in Canada: A Nationwide Study. *Anesthesia and analgesia* **124**, 890-897, doi:10.1213/ane.0000000000001877 (2017).

3 Beckett, V. A., Knight, M. & Sharpe, P. The CAPS Study: incidence, management and outcomes of cardiac arrest in pregnancy in the UK: a prospective, descriptive study. *BJOG : an international journal of obstetrics and gynaecology* **124**, 1374-1381, doi:10.1111/1471-0528.14521 (2017).

4 Dijkman, A. *et al.* Cardiac arrest in pregnancy: increasing use of perimortem caesarean section due to emergency skills training? *BJOG : an international journal of obstetrics and gynaecology* **117**, 282-287, doi:10.1111/j.1471-0528.2009.02461.x (2010).

5 McClure, J. H., Cooper, G. M. & Clutton-Brock, T. H. Saving mothers' lives: reviewing maternal deaths to make motherhood safer: 2006-8: a review. *British journal of anaesthesia* **107**, 127-132, doi:10.1093/bja/aer192 (2011).

6 Abella, B. S. High-quality cardiopulmonary resuscitation: current and future directions. *Current opinion in critical care* **22**, 218-224, doi:10.1097/mcc.0000000000000296 (2016).

7 Farinelli, C. K. & Hameed, A. B. Cardiopulmonary resuscitation in pregnancy. *Cardiology clinics* **30**, 453-461, doi:10.1016/j.ccl.2012.04.006 (2012).

8 Vanden Hoek, T. L. *et al.* Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* **122**, S829-861, doi:10.1161/circulationaha.110.971069 (2010).

9 Jeejeebhoy, F. M. *et al.* Management of cardiac arrest in pregnancy: a systematic review. *Resuscitation* **82**, 801-809, doi:10.1016/j.resuscitation.2011.01.028 (2011).

10 Bennett, T. A., Katz, V. L. & Zelop, C. M. Cardiac Arrest and Resuscitation Unique to Pregnancy. *Obstetrics and gynecology clinics of North America* **43**, 809-819, doi:10.1016/j.ogc.2016.07.011 (2016).

11 Lipman, S. *et al.* The Society for Obstetric Anesthesia and Perinatology consensus statement on the management of cardiac arrest in pregnancy. *Anesthesia and analgesia* **118**, 1003-1016, doi:10.1213/ane.0000000000000171 (2014).

12 Soar, J. *et al.* European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: Electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. *Resuscitation* **81**, 1400-1433, doi:10.1016/j.resuscitation.2010.08.015 (2010).

13 Katz, V. L., Dotters, D. J. & Droegemueller, W. Perimortem cesarean delivery. *Obstetrics and gynecology* **68**, 571-576 (1986).

14 Katz, V., Balderston, K. & DeFreest, M. Perimortem cesarean delivery: were our assumptions correct? *American journal of obstetrics and gynecology* **192**, 1916-1920; discussion 1920-1911, doi:10.1016/j.ajog.2005.02.038 (2005).

15 Einav, S., Kaufman, N. & Sela, H. Y. Maternal cardiac arrest and perimortem caesarean delivery: evidence or expert-based? *Resuscitation* **83**, 1191-1200, doi:10.1016/j.resuscitation.2012.05.005 (2012).

16 Meron, G. *et al.* Cardiopulmonary resuscitation-associated major liver injury. *Resuscitation* **75**, 445-453, doi:10.1016/j.resuscitation.2007.05.023 (2007).

17 Krischer, J. P., Fine, E. G., Davis, J. H. & Nagel, E. L. Complications of cardiac resuscitation. *Chest* **92**, 287-291 (1987).

18 Buschmann, C. T. & Tsokos, M. Frequent and rare complications of resuscitation attempts. *Intensive care medicine* **35**, 397-404, doi:10.1007/s00134-008-1255-9 (2009).

19 Bacq Y, R. C. in *Schiff's disease of the liver* (ed Maddrey WC Schiff ER; Sorrell MF) 1435-1457 (Lippincott, Williams, and Wilkins, 2004).

20 Wakim-Fleming, J. & Zein, N. N. The liver in pregnancy: disease vs benign changes. *Cleveland Clinic journal of medicine* **72**, 713-721 (2005).

21 Nelson, D. B., Dearmon, V. & Nelson, M. D. Spontaneous rupture of the liver during pregnancy: a case report. *Journal of obstetric, gynecologic, and neonatal nursing : JOGNN* **18**, 106-113 (1989).

22 Berris, B. The incidence of palpable liver and spleen in the postpartum period. *Canadian Medical Association journal* **95**, 1318-1319 (1966).

23 Baghirzada, L. & Balki, M. Maternal cardiac arrest in a tertiary care centre during 1989-2011: a case series. *Canadian journal of anaesthesia = Journal canadien d'anesthesie* **60**, 1077-1084, doi:10.1007/s12630-013-0021-9 (2013).

24 King, S. E. & Gabbott, D. A. Maternal cardiac arrest--rarely occurs, rarely researched. *Resuscitation* **82**, 795-796, doi:10.1016/j.resuscitation.2011.03.029 (2011).

25 Bakhbakhi, D., Gamaleldin, I. & Siassakos, D. Cardiopulmonary resuscitation of pregnant women. *Resuscitation* **91**, A5-6, doi:10.1016/j.resuscitation.2015.03.018 (2015).

26 Kaplon-Cieslicka, A. *et al.* Coronary artery dissection, traumatic liver and spleen injury after cardiopulmonary resuscitation - a case report and review of the literature. *Archives of medical science : AMS* **9**, 1158-1161, doi:10.5114/aoms.2013.39235 (2013).

27 Beydilli, H. *et al.* Liver laceration related to cardiopulmonary resuscitation. *Turkish journal of emergency medicine* **16**, 77-79, doi:10.1016/j.tjem.2015.01.002 (2016).

28 Shinohara, S., Uchida, Y., Kasai, M., Ogawa, T. & Hirata, S. Liver injury after cardiopulmonary resuscitation for cardiac arrest during cesarean delivery. *International journal of obstetric anesthesia* **29**, 86-87, doi:10.1016/j.ijoa.2016.09.007 (2017).

29 Druwe, P. M., Cools, F. J., De Raedt, H. J. & Bossaert, L. L. Liver rupture after cardiopulmonary resuscitation in a patient receiving thrombolytic therapy. *Resuscitation* **32**, 213-216 (1996).

30 Zahn, G., Hauck, M., Pearson, D. A., Green, J. M. & Heffner, A. C. Major hemorrhage from hepatic laceration after cardiopulmonary resuscitation. *The American journal of emergency medicine* **33**, 991.e993-994, doi:10.1016/j.ajem.2014.12.048 (2015).
31 Monsuez, J. J. *et al.* Subcapsular liver haematoma after cardiopulmonary resuscitation by untrained personnel. *Resuscitation* **73**, 314-317, doi:10.1016/j.resuscitation.2006.08.017 (2007).
32 Holmes, S., Kirkpatrick, I. D., Zelop, C. M. & Jassal, D. S. MRI evaluation of maternal cardiac displacement in pregnancy: implications for cardiopulmonary resuscitation. *American journal of obstetrics and gynecology* **213**, 401.e401-405, doi:10.1016/j.ajog.2015.05.018 (2015).
33 Chapman, A. B. *et al.* Temporal relationships between hormonal and hemodynamic changes in early human pregnancy. *Kidney international* **54**, 2056-2063, doi:10.1046/j.1523-1755.1998.00217.x (1998).
34 Adeyeye, V. O. *et al.* Echocardiographic Assessment of Cardiac Changes During Normal Pregnancy Among Nigerians. *Clinical Medicine Insights. Cardiology* **10**, 157-162, doi:10.4137/cmc.s40191 (2016).
35 Mogos, M. F., Salemi, J. L., Spooner, K. K., McFarlin, B. L. & Salihu, H. M. Differences in Mortality Between Pregnant and Nonpregnant Women After Cardiopulmonary Resuscitation. *Obstetrics and gynecology* **128**, 880-888, doi:10.1097/aog.0000000000001629 (2016).
36 Lavecchia, M. & Abenhaim, H. A. Cardiopulmonary resuscitation of pregnant women in the emergency department. *Resuscitation* **91**, 104-107, doi:10.1016/j.resuscitation.2015.01.017 (2015).

Table legends:

Table 1. Eleven women at a single tertiary referral center with cardiac arrest and CPR performed during the peripartum period.

ROSC=return of spontaneous circulation, C/S=caesarean section, TTP=thrombotic thrombocytopenic purpura, HUS=hemolytic uremic syndrome, DIC=disseminated intravascular coagulation, PE=pulmonary embolism, GDM=gestational diabetes mellitus, CKD=chronic kidney disease, ECMO=extracorporeal membrane oxygenation

Table 2. Three women who experienced liver injury after peripartum CPR.

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Abstract

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Methods: We identified pregnancies complicated by cardiac arrest by performing a retrospective medical record review from 2011-2016 at a single tertiary referral hospital. We then compared the rate of liver lacerations in this group to the rate in the general population as found in the literature.

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Conclusions: Based on a small retrospective study, liver lacerations requiring intervention occurred in 43% of gravidas patients that survived CPR, and is significantly higher than published rates (0.6-2.1%) for the general patient population. Further studies are indicated to determine if this rate of liver injury associated with peripartum CPR. ~~Liver laceration more frequently afflicts women in the peripartum period who suffer cardiac arrest and receive CPR than what is reported in the general population. Liver laceration contributes to an overall poor outcome after cardiac arrest, even after successful return of spontaneous circulation.~~

Introduction

Maternal cardiac arrest is a rare, frightening and devastating event, often resulting in the demise of the mother, fetus/neonate or both. The most common cause of maternal cardiac arrest is haemorrhage, accounting for up to 40% of all cases.[1-3] The reported rate of CPR among the peripartum population within developed countries ranges from 1:53,260 (0.019%) to 1:11,749 (0.0085%).[1-5]

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Case 1

A 34-year-old G6P3, presented to Labor & Delivery at 31 weeks' gestation with abdominal pain and leakage of fluid. She had a history of diabetes mellitus (type 1), hypertension and chronic kidney disease. Her calculated BMI was 25 m^2/kg. She was diagnosed with preterm premature rupture of membranes. She was started on magnesium sulfate and steroids were administered. Shortly after administration of the magnesium, she became unresponsive and it

was thought she had a seizure. Immediately following emergent delivery by cesarean section, the patient experienced cardiopulmonary arrest and ACLS was started. ROSC occurred fifteen minutes later. Massive abdominal haemorrhage continued after closure of the uterine incision; a hysterectomy was performed. She continued in shock despite massive transfusion and intravenous infusion of vasopressors. Further abdominal exploration revealed liver injury, including a: large (right lobe) subcapsular hematoma; laceration adjacent to the gallbladder; and, separate left infra-lobar laceration. Her postoperative course deteriorated further in the intensive care unit (ICU). Despite heroic measures, she remained unresponsive with evidence of brain death, expiring after termination of further resuscitative efforts.

Case 2

A 35-year-old G3P2 presented to an outside hospital (OSH) at 38 weeks' gestation with confusion, agitation, tachypnea and cyanosis. She offered no significant medical history. Her calculated BMI was 21 m^2/kg. Diagnosed with a pulmonary embolism, tPA (50mg) was intravenously infused. Manifesting maternal shock and with a category III fetal heart rate pattern displayed on the electronic fetal heart rate monitor, she underwent abdominal delivery. In the immediate postpartum period, she was transferred to UMMC for veno-arterial ECMO. During cannulation of the right femoral artery, she lapsed into cardiac arrest. ACLS was initiated and ROSC was noted ten minutes later. A hysterectomy was performed for massive vaginal hemorrhage. Further abdominal exploration revealed liver injury including a ruptured subcapsular hematoma and a large infra-lobar (right) laceration. Echocardiography revealed a large left ventricular thrombus. Resuscitation, including hepatic artery embolization, was continued but unsuccessful and the patient expired the same day.

Case 3

A 24-year-old G3P2 presented to an OSH at 40 weeks' gestation in active labor. She had a history of uterine fibroids. Her calculated BMI was 28 m^2/kg. She underwent vacuum-assisted vaginal delivery. Subsequent massive (vaginal) haemorrhage, with clinical and laboratory signs of coagulopathy, led to hysterectomy. In the ICU, she suffered cardiac arrest. ACLS was performed; ROSC occurred. With continued clinical/laboratory signs of abdominal hemorrhage, the patient returned to the OR. Laparotomy revealed hepatic injury including a large linear infra-lobar (right) laceration and a large subcapsular hematoma of the dome. She remained

haemodynamically unstable even after embolization of the distal right hepatic artery. She was transferred to UMMC. She was stabilized and her coagulopathy corrected. Damage-control exploration of her abdomen was performed followed ten days later by a delayed primary closure. The patient recovered and continues to do well.

Discussion

Added to the normally tumultuous scene occurring at any cardiac arrest, having a pregnant patient who requires CPR heightens anxiety for all healthcare providers involved. Furthermore, the scenario can become more complicated if they must prepare for a perimortem caesarean section (PMCS) if there is no return of spontaneous circulation within an ideal goal of four minutes.[8-11,13-15]

The rate of CPR in the peripartum population of developed countries varies, including: The Netherlands (0.0019%)[4]; Scotland (0.002%)[5]; United Kingdom (0.0028-0.0063%)[3]; Canada (0.008%)[2]; and, the United States (0.085%).[1] A study of maternal cardiac arrest in a Canadian tertiary care center reported a rate of 1:24,883 (0.004%), but excluded postpartum circulatory arrests.[23]

The peripartum CPR rate seen at our institution is almost 15-fold (0.12% vs. 0.0085%) higher as compared to published rates.[1] A factor likely skewing our results is that as a tertiary care referral center, many of our obstetric patients are transferred from other hospitals where they have already been diagnosed with significant complications of pregnancy. This is in additiong to our hospitals' own high-acuity, high-risk obstetric patient population. Indeed, five of the 11 patients in this report were transferred to our facility (Table 1).

Liver injury after CPR in peripartum patients has not been well-studied.[24,25] We could not find any comparisons of injury rates between women in the peripartum period undergoing CPR and those reported in the general population. Among the general population, reports on complications associated with CPR reveal the majority of complications are non-life threatening (e.g., rib fractures), while more severe complications (e.g., liver injury) are rare. In 1987, Krischer, *et al*., found the incidence of liver rupture to be 2.1%, in addition to "other liver injuries" at 0.8%, putting the total incidence of liver injury at 2.9%.[17] A more recent study put

the overall rate at 0.6%, with an even lower rate of 0.5% in women.[16] Published case reports of liver injury after CPR indicate that the complication was typically significant, resulting in hemorrhage and death.[18,26,27] Two other case reports are reported of liver injury during CPR in pregnancy.[21,28] Outside of pregnancy, a few case reports have purposed the reasoning for clinically significant liver injury is secondary to coagulopathy.[16,27,29,30] or untrained personnel.[31] Our rate of clinically significant liver injury associated with CPR in pregnancy (27%) is likewise much higher than the published rates of liver laceration associated with CPR in the general population (0.6-2.1%). Two of the three patients were coagulopathic prior to arrest and this may have played a significant role in the mechanism of injury to the liver. .

We can proffer an explanation for this increased rate of liver injury associated with CPR, partially due to the physiologic changes in pregnancy. One study found no significant rostral displacement of the heart in pregnancy; challenging the dogma of pregnancy-associated elevation of the diaphragm.[32]This suggests the diaphragm acts as a "rigid wall" enclosing the abdominal organs. An enlarged uterus during pregnancy and even in the postpartum period results in less abdominal capacity and possibily physiologic compression of the liver capsule. In addition, increased intravascular volume and hepatic congestion as noted by other authors[7,20,22,33,34] could potentially increase hepatic susceptibility to injury. More work, however, is needed to confirm this increased incidence of clinically important liver lacerations in peripartum patients, and to evaluate possible etiologies for this difference.

The major limitation of this study is that it is a retrospective case series of a rare event at a single institution. Additionally, we are unable to determine whether the rate of liver injury after CPR is specific to our high-acuity hospital as we did not calculate the period prevalence in non-pregnant patients. The survival to discharge rates for all patients receiving CPR at our institution is 25.0% which is similar to the findings of our study. A recent study, however, demonstrates that CPR in pregnancy has a better prognosis than non-pregnant individuals.[35,36] Due to the limitations of record review, we were often unable to find details of the CPR performed, including hand position during closed chest massage or if any bedside alterations were made to resuscitation methods promulgated in the AHA guidelines for peripartum CPR. We were unable to account for confounding variables associated with coagulopathy in critically-ill gravidae, such as Thrombotic Thrombocytopenia Purpura (TTP), Disseminated Intravascular Coagulation

(DIC), or pre-eclampsia. All three patients who suffered liver lacerations developed DIC, two prior to CPR and the other after successful resuscitation.

More accurate rates of both peripartum CPR and associated liver lacerations could be revealed in a future study including data from multiple states- or nation-wide hospitals as well as for a period longer than six years. This would allow for comparison of rates in age-matched and non-pregnant women. If there is a pre-disposition to liver laceration in pregnant women then nation-wide results might validate or support change in current guidelines for CPR in peripartum women. Thought should be given to performing either surgical exploration, abdominal ultrasound to evaluate for intra-abdominal free fluid, or CT evaluation of the upper abdomen in all gravidae who remain haemodynamically unstable after cardiopulmonary resuscitation. A shorter time-to-diagnosis of liver injury might increase the efficacy of available surgical and non-surgical interventions to prevent complications of massive haemorrhage, transfusion and shock.

Conclusions

Based on this small retrospective case series at our tertiary care, obstetric and trauma referral hospital, liver lacerations requiring intervention occurred in 43% of gravidae patients who survived CPR, and is significantly higher than published rates (0.6-2.1%) for the general patient population. Further studies are indicated to determine if this rate of liver injury associated with peripartum CPR is generalizable beyond our hospital. We believe that recognition of its increased prevalence, and early consideration for the diagnosis allows for rapid treatment of this life threatening complication, and may allow for an improvement in outcomes for these unfortunate patients.

Conflicts of interest: None.

Individual Contributions of the Authors:

Timothy Cox: Conceived, primarily researched and prepared data, wrote and edited the final manuscript.

Sarah Crimmins: Primarily conceived, wrote and edited the final manuscript

Allison Shannon: Researched and edited the final manuscript

Kristin Atkins: Conceived and edited the final manuscript

Ronald Tesoriero: Facilitated research and edited the final manuscript

Andrew Malinow: Facilitated research, wrote and edited the final manuscript

References

1 Mhyre, J. M. *et al.* Cardiac arrest during hospitalization for delivery in the United States, 1998-2011. *Anesthesiology* **120**, 810-818, doi:10.1097/aln.0000000000000159 (2014).

2 Balki, M., Liu, S., Leon, J. A. & Baghirzada, L. Epidemiology of Cardiac Arrest During Hospitalization for Delivery in Canada: A Nationwide Study. *Anesthesia and analgesia* **124**, 890-897, doi:10.1213/ane.0000000000001877 (2017).

3 Beckett, V. A., Knight, M. & Sharpe, P. The CAPS Study: incidence, management and outcomes of cardiac arrest in pregnancy in the UK: a prospective, descriptive study. *BJOG : an international journal of obstetrics and gynaecology* **124**, 1374-1381, doi:10.1111/1471-0528.14521 (2017).

4 Dijkman, A. *et al.* Cardiac arrest in pregnancy: increasing use of perimortem caesarean section due to emergency skills training? *BJOG : an international journal of obstetrics and gynaecology* **117**, 282-287, doi:10.1111/j.1471-0528.2009.02461.x (2010).

5 McClure, J. H., Cooper, G. M. & Clutton-Brock, T. H. Saving mothers' lives: reviewing maternal deaths to make motherhood safer: 2006-8: a review. *British journal of anaesthesia* **107**, 127-132, doi:10.1093/bja/aer192 (2011).

6 Abella, B. S. High-quality cardiopulmonary resuscitation: current and future directions. *Current opinion in critical care* **22**, 218-224, doi:10.1097/mcc.0000000000000296 (2016).

7 Farinelli, C. K. & Hameed, A. B. Cardiopulmonary resuscitation in pregnancy. *Cardiology clinics* **30**, 453-461, doi:10.1016/j.ccl.2012.04.006 (2012).

8 Vanden Hoek, T. L. *et al.* Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* **122**, S829-861, doi:10.1161/circulationaha.110.971069 (2010).

9 Jeejeebhoy, F. M. *et al.* Management of cardiac arrest in pregnancy: a systematic review. *Resuscitation* **82**, 801-809, doi:10.1016/j.resuscitation.2011.01.028 (2011).

10 Bennett, T. A., Katz, V. L. & Zelop, C. M. Cardiac Arrest and Resuscitation Unique to Pregnancy. *Obstetrics and gynecology clinics of North America* **43**, 809-819, doi:10.1016/j.ogc.2016.07.011 (2016).

11 Lipman, S. *et al.* The Society for Obstetric Anesthesia and Perinatology consensus statement on the management of cardiac arrest in pregnancy. *Anesthesia and analgesia* **118**, 1003-1016, doi:10.1213/ane.0000000000000171 (2014).
12 Soar, J. *et al.* European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: Electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. *Resuscitation* **81**, 1400-1433, doi:10.1016/j.resuscitation.2010.08.015 (2010).
13 Katz, V. L., Dotters, D. J. & Droegemueller, W. Perimortem cesarean delivery. *Obstetrics and gynecology* **68**, 571-576 (1986).
14 Katz, V., Balderston, K. & DeFreest, M. Perimortem cesarean delivery: were our assumptions correct? *American journal of obstetrics and gynecology* **192**, 1916-1920; discussion 1920-1911, doi:10.1016/j.ajog.2005.02.038 (2005).
15 Einav, S., Kaufman, N. & Sela, H. Y. Maternal cardiac arrest and perimortem caesarean delivery: evidence or expert-based? *Resuscitation* **83**, 1191-1200, doi:10.1016/j.resuscitation.2012.05.005 (2012).
16 Meron, G. *et al.* Cardiopulmonary resuscitation-associated major liver injury. *Resuscitation* **75**, 445-453, doi:10.1016/j.resuscitation.2007.05.023 (2007).
17 Krischer, J. P., Fine, E. G., Davis, J. H. & Nagel, E. L. Complications of cardiac resuscitation. *Chest* **92**, 287-291 (1987).
18 Buschmann, C. T. & Tsokos, M. Frequent and rare complications of resuscitation attempts. *Intensive care medicine* **35**, 397-404, doi:10.1007/s00134-008-1255-9 (2009).
19 Bacq Y, R. C. in *Schiff's disease of the liver* (ed Maddrey WC Schiff ER; Sorrell MF) 1435-1457 (Lippincott, Williams, and Wilkins, 2004).
20 Wakim-Fleming, J. & Zein, N. N. The liver in pregnancy: disease vs benign changes. *Cleveland Clinic journal of medicine* **72**, 713-721 (2005).
21 Nelson, D. B., Dearmon, V. & Nelson, M. D. Spontaneous rupture of the liver during pregnancy: a case report. *Journal of obstetric, gynecologic, and neonatal nursing : JOGNN* **18**, 106-113 (1989).
22 Berris, B. The incidence of palpable liver and spleen in the postpartum period. *Canadian Medical Association journal* **95**, 1318-1319 (1966).
23 Baghirzada, L. & Balki, M. Maternal cardiac arrest in a tertiary care centre during 1989-2011: a case series. *Canadian journal of anaesthesia = Journal canadien d'anesthesie* **60**, 1077-1084, doi:10.1007/s12630-013-0021-9 (2013).
24 King, S. E. & Gabbott, D. A. Maternal cardiac arrest--rarely occurs, rarely researched. *Resuscitation* **82**, 795-796, doi:10.1016/j.resuscitation.2011.03.029 (2011).
25 Bakhbakhi, D., Gamaleldin, I. & Siassakos, D. Cardiopulmonary resuscitation of pregnant women. *Resuscitation* **91**, A5-6, doi:10.1016/j.resuscitation.2015.03.018 (2015).
26 Kaplon-Cieslicka, A. *et al.* Coronary artery dissection, traumatic liver and spleen injury after cardiopulmonary resuscitation - a case report and review of the literature. *Archives of medical science : AMS* **9**, 1158-1161, doi:10.5114/aoms.2013.39235 (2013).
27 Beydilli, H. *et al.* Liver laceration related to cardiopulmonary resuscitation. *Turkish journal of emergency medicine* **16**, 77-79, doi:10.1016/j.tjem.2015.01.002 (2016).
28 Shinohara, S., Uchida, Y., Kasai, M., Ogawa, T. & Hirata, S. Liver injury after cardiopulmonary resuscitation for cardiac arrest during cesarean delivery. *International journal of obstetric anesthesia* **29**, 86-87, doi:10.1016/j.ijoa.2016.09.007 (2017).
29 Druwe, P. M., Cools, F. J., De Raedt, H. J. & Bossaert, L. L. Liver rupture after cardiopulmonary resuscitation in a patient receiving thrombolytic therapy. *Resuscitation* **32**, 213-216 (1996).

30 Zahn, G., Hauck, M., Pearson, D. A., Green, J. M. & Heffner, A. C. Major hemorrhage from hepatic laceration after cardiopulmonary resuscitation. *The American journal of emergency medicine* **33**, 991.e993-994, doi:10.1016/j.ajem.2014.12.048 (2015).
31 Monsuez, J. J. *et al.* Subcapsular liver haematoma after cardiopulmonary resuscitation by untrained personnel. *Resuscitation* **73**, 314-317, doi:10.1016/j.resuscitation.2006.08.017 (2007).
32 Holmes, S., Kirkpatrick, I. D., Zelop, C. M. & Jassal, D. S. MRI evaluation of maternal cardiac displacement in pregnancy: implications for cardiopulmonary resuscitation. *American journal of obstetrics and gynecology* **213**, 401.e401-405, doi:10.1016/j.ajog.2015.05.018 (2015).
33 Chapman, A. B. *et al.* Temporal relationships between hormonal and hemodynamic changes in early human pregnancy. *Kidney international* **54**, 2056-2063, doi:10.1046/j.1523-1755.1998.00217.x (1998).
34 Adeyeye, V. O. *et al.* Echocardiographic Assessment of Cardiac Changes During Normal Pregnancy Among Nigerians. *Clinical Medicine Insights. Cardiology* **10**, 157-162, doi:10.4137/cmc.s40191 (2016).
35 Mogos, M. F., Salemi, J. L., Spooner, K. K., McFarlin, B. L. & Salihu, H. M. Differences in Mortality Between Pregnant and Nonpregnant Women After Cardiopulmonary Resuscitation. *Obstetrics and gynecology* **128**, 880-888, doi:10.1097/aog.0000000000001629 (2016).
36 Lavecchia, M. & Abenhaim, H. A. Cardiopulmonary resuscitation of pregnant women in the emergency department. *Resuscitation* **91**, 104-107, doi:10.1016/j.resuscitation.2015.01.017 (2015).

Table legends:

Table 1. Eleven women at a single tertiary referral center with cardiac arrest and CPR performed during the peripartum period.

ROSC=return of spontaneous circulation, C/S=caesarean section, TTP=thrombotic thrombocytopenic purpura, HUS=hemolytic uremic syndrome, DIC=disseminated intravascular coagulation, PE=pulmonary embolism, GDM=gestational diabetes mellitus, CKD=chronic kidney disease, ECMO=extracorporeal membrane oxygenation

Table 2. Three women who experienced liver injury after peripartum CPR.

Table

Pt	*Age*	*Race*	*BMI*	*Comorbidities*	*Acute condition precipitating CPR*	*Gestational age*	*Delivery*	*Timing of arrest*	*Location of arrest*	*Length of CPR (minutes)*	*ROSC*	*Liver injury*	*Status*
1	34	AA	25	T1DM, HTN, CKD	Pre-eclampsia, respiratory arrest	31-0	C/S	Immediately	In-hospital, OB OR	15	Yes	Yes	Died next day
2	35	As	21	None	(Transfer) Suspected PE	38-0	C/S	Day of delivery	In-hospital, CCRU during ECMO can	10	Yes	Yes	Died same day
3	41	AA	29	Fibroids	(Transfer) Haemorrhage	40-0	Vacuum-assisted	Day of delivery	OSH - ICU	-	Yes	Yes	Alive
4	24	AA	55	GDM, morbid obesity	Haemorrhage	36-1	C/S	Day of delivery	In-hospital – L&D RN	15	Yes	No	Alive
5	28	W	42	TTP, bipolar	TTP-HUS	32-6	C/S	32-6 weeks gestation	In-hospital - MICU	79	No	No	Died at time of arrest
6	38	W	48	GDM, obesity, HTN, B-cell ALL, eclampsia in prior pregnancy, pernicious anemia	-	Post-partum, delivered at 29-5	C/S	Day of Delivery	In-hospital – Cancer center	18	Yes	No	Died next day
7	26	W	26	Unknown. s/p MVC	(Transfer) Arrest s/p MVC	22-5	Vaginal	22-5 weeks gestation	On scene, EMS	-	Yes	No	Died 3 days after
8	27	W	25	Hypothyroidism	(Transfer) Peritonitis & shock	Postpartum, delivered at 40-0	Vaginal	8 days postpartum	Trauma OR	45	No	No	Died at time of arrest
9	29	AA	25	None	(Transfer) DIC, PE	38-2	C/S	Postpartum (1 day)	OSH PACU	2	Yes	No	Died 2 days after
10	39	AA	33	GDM, HTN, Hep C, IVDA	Ascending aortic dissection w/ haemopericardium	33-3	C/S	Postpartum (1 day)	In-hospital, MICU	16	No	No	Died at time of arrest
11	33	AA	26	Pre-eclampsia	HELLP syndrome, DIC, shock	39-4	C/S	Day of Delivery	Trauma OR	30	No	No	Died at time of arrest

Table 1. Eleven women at a single tertiary referral center with cardiac arrest and CPR performed during the peripartum period.
ROSC=return of spontaneous circulation, C/S=caesarean section, TTP=thrombotic thrombocytopenic purpura, HUS=hemolytic uremic syndrome, DIC=disseminated intravascular coagulation, PE=pulmonary embolism, GDM=gestational diabetes mellitus, CKD=chronic kidney disease, ECMO=extracorporeal membrane oxygenation

Pt	*Gestational age*	*Complications*	*Hysterectomy*	*Timing of arrest*	*Length of CPR (minutes)*	*ROSC*	*Liver injury from CPR*	*Complications post-resuscitation*	*Status*
1	31-0	Eclampsia, respiratory arrest,	Yes	During delivery	15	Yes	R & L Liver lacerations	Haemorrhage, DIC	Died day after CPR
2	32-0	Suspected PE, Thrombolytics	Yes	Day of Delivery	10	Yes	2 R Liver lacerations	Haemorrhage, DIC	Died same day as CPR
3	40-0	Haemorrhage, DIC	Yes	Day of delivery	-	Yes	R Liver laceration	DIC	Alive

Table 2. Three women who experienced liver injury after peripartum CPR.

*Conflict of Interest Statement - COX

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We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Manuscript: Liver lacerations as a complication of CPR during pregnancy

Sincerely,

Timothy R Cox, MSIV _____ Date 7/24/19

Sarah Crimmins, DO _____ Date 7/24/19

Allison Shannon, MD _____ Date _____

Kristin L Atkins, MD _____ Date _____

Ronald Tesoriero, MD _____ Date _____

Andrew M. Malinow, MD _____ Date _____

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