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Case Report / Приказ случаја

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The possible underlying mechanism of gastric mucosal ruptures due to resuscitation efforts

Могући механизам настанка расцепа слузокоже желуца при кардиопулмоналној реанимацији

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SUMMARY

Introduction The occurrence of gastric mucosal ruptures during cardiopulmonary resuscitation (CPR) was contributed to extensive gastric distention, either due to mouth-to-mouth resuscitation or the use of a bag and mask, or inappropriate intubation that may lead to gastric hyperinflation, which then creates gastric distension and further promotes gastric rupture. The presented case suggests that there might be another mechanism – chest compression during CPR.

Case Outline We presented a case of 84-year old woman who died due to severe chronic ischemic heart disease after unsuccessful resuscitation. The autopsy revealed a presence of several shallow ruptures of gastric mucosa on lesser curvature, 1 to 3 cm in length, with surrounding mucosal hemorrhage, and without bleeding in gastric cavity.

Conclusion Gastric mucosal ruptures could occur due to a combination of these two mechanisms: pressure propagation due to chest compression and gastric hyperinflation.

Keywords: cardiopulmonary resuscitation; gastric mucosal ruptures; autopsy

Сажетак

Увод Кардиопулмонална реанимација (КПР) може да доведе до настанка расцепа слузокоже желуца, јер методом „уста на уста”, употребом балон-маске или неадекватном интубацијом, долази до хиперинфлације и дистензије желуца, а потом, у неким случајевима, и до расцепа слузокоже. Случај који приказујемо сугерише да би механизам могао да буде притисак на грудни кош приликом КПР.

Приказ случаја Жена, стара 84 године, код које је смрт наступила услед погоршања хроничне исхемијске болести срца и неуспешне реанимације. Обдукцијом је установљено присуство неколико плитких расцепа слузокоже желуца дуж мале кривине, дужине око 1–3 цм, без крварења у дупљи желуца.

Закључак Расцепи слузокоже желуца могу настати као комбинација два механизма током реанимације: пропагације притиска услед притиска на грудни кош и хиперинфлације желуца.

Кључне речи: кардиопулмонална реанимација; расцепи слузокоже желуца; обдукција

INTRODUCTION

Radial superficial ruptures of the gastric mucosa are related to cardiopulmonary resuscitation (CPR), occurring in about 12% of cases [1, 2, 3, 4]. However, these are mostly case series or case reports, while there are only a small number of clinical or autopsy studies. In these papers the occurrence of gastric mucosal ruptures was contributed to extensive gastric distention, either due to mouth-to-mouth resuscitation or the use of a bag and mask, or even inappropriate intubation that may lead to gastric hyperinflation, which then creates gastric distension and further promotes gastric rupture [1, 2, 3].

However, we believe that the mechanism of gastric mucosal tears could be different, and that it is not exclusively related to gastric hyperinflation and artificial ventilation, although still closely related to CPR. Although many authors consider the gastric distension as the cause of gastric mucosal ruptures, it seems reasonable that there might be another mechanism – chest compression during CPR, i.e. external cardiac massage, regardless of the gastric hyperinflation presence.

CASE OUTLINE

A 86-year old woman died shortly after admission to a local hospital, after unsuccessful CPR, which was conducted with a bag valve mask (i.e. Ambu mask), without intubation. The autopsy,

performed the following day, revealed severe chronic ischemic heart disease, with acute myocardial infarct surrounding the area of fibrous scar, as a cause of death. Bilateral fractures from second to seventh rib in anterior anatomic lines, as well as fracture of sternum, without pleural rupture were attributed to CPR. Additional findings were several shallow ruptures of gastric mucosa on lesser curvature, 1 to 3 cm in length, with surrounding mucosal hemorrhage (Figure 1a and 1b), and without bleeding in gastric cavity. Also, subcapsular hemorrhages on the upper side of left lobe of the liver were found, along with ruptures of gastric mucosa, also attributed to CPR (Figure 1c and 1d). These findings were confirmed by microscopic examination. There were no signs of gastric hyperinflation.

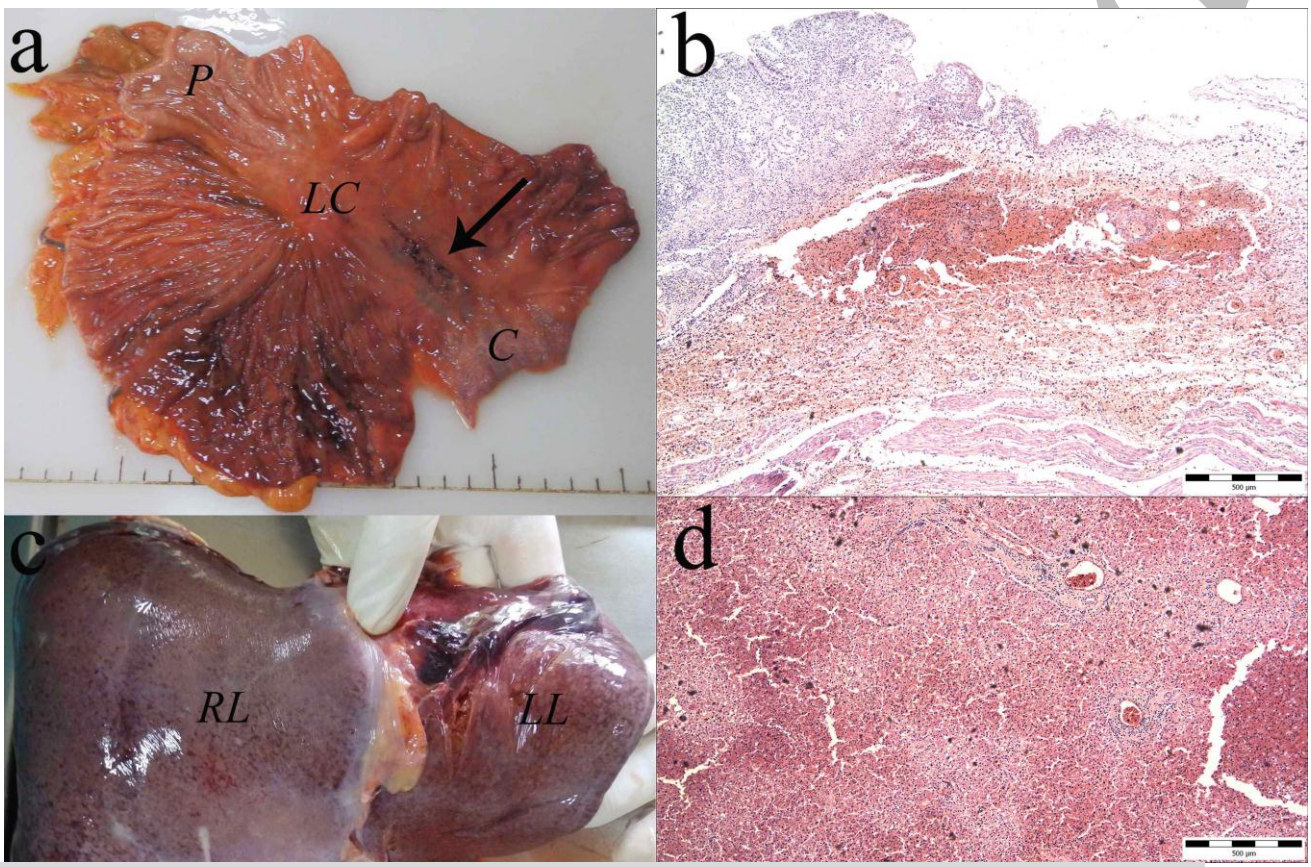

Figure 1. An 84-year-old man who died in hospital due to myocardial infarction. Bilateral rib fractures due to CPR were present. a Macroscopic and b microscopic appearance of shallow longitudinal gastric mucosa ruptures on the lesser curvature, mostly along the long axis of the stomach, parallel to the vertebral column, with surrounding bleeding encompassing submucosa and mucularis mucosae, without extension to serosa. *C* – cardia, *LC* – lesser curvature, *P* – pylorus; c Subcapsular hemorrhages on the upper side of the left lobe, localized in the sagittal plane. d The microscopic appearance of radial micro cracks in the liver tissue, propagating in all directions, thus showing ways of force propagation through hepatic tissues due to chest compression in CPR. *RL* – right lobe, *LL* – left lobe.

DISCUSSION

Injuries of the stomach and intestines may be caused by forces of compression or crushing forces, traction or tearing forces, and forces of disruption or bursting forces. When a force is applied to the anterior abdominal wall, the force may be transmitted through the muscles and may compress the stomach or intestines against the rigid posterior abdominal wall [5]. Typically, gastric ruptures from resuscitation occur along or parallel to the lesser curvature below the gastro-esophageal junction,

or may have the appearance of a "lightning bolt" [2]. They are less common than other autopsy findings associated with unsuccessful CPR – serial rib fractures due to external cardiac massage, or retropharyngeal bleedings, tooth damage, and pharyngeal mucosa lesions caused by multiple intubation attempts [1, 2].

Figure 1 represents our case with gastric mucosal ruptures, occurring in older person, after unsuccessful CPR and without signs of gastric hyperinflation. The ruptures are on the lesser curvature, mostly along the long axis of the stomach, parallel to the vertebral column (Fig. 1a). Holotopic and syntopic relations of the stomach with the liver and vertebral column, still unchanged with early post-mortem changes, including early muscular flaccidity, could explain the pressure propagation towards the stomach during chest compression with the occurrence of longitudinal ruptures. One should keep in mind that unlike in an autopsy where the stomach is limp and positioned in the frontal plane, in a living person the stomach has an approximate shape of the letter "J" and its position is different – the lesser curvature is practically in the sagittal plane, closer to the left side of the vertebral column [6].

According to the Pascal's law or the principle of fluid-pressure transmission, a principle in fluid mechanics, a pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid in such a way that the pressure variations (initial differences) remain the same [7]. Pascal's law can be applied in CPR – during chest compression, pressure is transmitted in all directions, including the upper part of the stomach, the liver and surrounding soft tissue structures. In this way, the visceral organs of the upper abdomen are compressed against the rigid posterior wall of the abdominal cavity and vertebral column. This pressure may lead to mucosal gastric ruptures, as well as hepatic ruptures, localized in the sagittal plane (Fig. 1), hence perpendicularly to the direction of chest compression. In the presented case, microscopic examination showed radial micro cracks in the liver tissue propagating in all directions (Fig. 1d). These microscopic cracks follow the lobular hepatic structure and its weak spots, and they are spread radially, thus showing ways of force propagation through hepatic tissues due to chest compression in CPR.

In most of the described cases, including the case presented here (Fig. 1), gastric mucosal ruptures appeared along the lesser curvature, parallel to the long axis of the stomach [1, 2]. The occurrence of aortic rupture, relatively common in forensic practice, could be often explained by caudo-rostal stretching, and in these cases ruptures are transverse and the fibers closest to the intima break first [8], relatively perpendicularly to the direction of stretching. Analogously, during CPR, the stomach finds itself between the sternum and vertebral column. The pressure is then applied from back to front, but due to the resistance provided by the posterior abdominal wall and the structures behind it (analogous to the osseous pinch mechanism in aortic ruptures), the direction of the applied force causes lateral stretching of the fibers in the stomach, i.e. it expands the gastric wall to the left and right. Since the lesser curvature is in the sagittal plane, parallel to the vertebral column and in its

close proximity, gastric mucosal ruptures occur along the lesser curvature, hence perpendicularly to the direction of chest compression and stretching. Again, analogously to the aorta (where the intima breaks first), the mucosa ruptures first – in both cases breaks occur from the inside towards the outside layers. Also, the experimental biomechanical study on the porcine stomach can support this scenario, showing that the longitudinal strips are more susceptible to rupture compared to circumferential and other strips [9]. Again, according to this it could be expected that rupture would occur not on the mucosal side of the stomach, but on the serosa. Namely, the curved wall makes additional pressure inside the gastric cavity, which is directly proportional to the curve radius according to Laplace's law. That means that lesser force is needed to break serosa than to break mucosa. However, we do not see serosal, but mucosal ruptures in such cases. Analogously, in cases of suicide by a firearm placed in the mouth, the discharge of a high-powered firearm into the mouth is associated with a tremendous rise of intraoral pressure and the overexpansion of the soft tissues of the head and massive fractures of the skull, but this also causes vertical tears of the skin on the cheeks, and not necessarily on the oral mucosa [10].

The reason for gastric hyperinflation in such cases might sometimes lie in the cause of death – fatal loss of blood. Some clinicians claim that a person suffering from acute hemorrhage is anxious and restless, and shows signs of "air hunger" [5]. Significant blood loss leads to hypoxia, and then to hyperventilation, which further leads to the phenomenon called "air hunger" – air entering the stomach by successive acts of swallowing [11, 12]. This phenomenon is commonly seen in dying patients in the intensive care unit [11, 12]. Therefore, the presence of gastric hyperinflation in the case of fatal blood loss did not necessarily have to be the consequence of inadequate artificial ventilation, applied by bystanders or medical staff, but the consequence of the inflicted injuries and fatal blood loss.

The main underlying mechanism for gastric mucosal ruptures during CPR could be the chest compression, with the pressure propagation from the sternum towards deeper visceral structures, including the stomach. Holotopic and syntopic relations of the stomach with the liver and vertebral column, still unchanged with early post-mortem changes, including early muscular flaccidity, could explain the pressure propagation towards the stomach during chest compression with the occurrence of longitudinal ruptures. In the least, these ruptures could occur due to a combination of these two mechanisms: pressure propagation due to chest compression and gastric hyperinflation (in cases where it undoubtedly existed). Perhaps a future prospective study might explain the predominant underlying mechanism(s).

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