Gastric pressure and volume were measured in 20 pregnant women during emergency Caesarean section under general anaesthesia with neuromuscular block. Mean gastric pressure was 11 (range 4–19) mm Hg and we can predict that 99% of women undergoing emergency Caesarean section with neuromuscular block are likely to have gastric pressures of less than 25 mm Hg (mean ± 3 SD). This has implications for the amount of cricoid pressure required during induction of anaesthesia. Gastric pressure increased during delivery to 19 mm Hg and fundal pressure caused a gastric pressure of 65 mm Hg in one woman. Gastric pressure decreased significantly after delivery \((P < 0.001)\) to 8 mm Hg. Although we measured large gastric volumes (mean 112 (range 20–350) ml), there was no correlation between gastric volume and gastric pressure.

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Cricoid pressure is applied routinely during induction of general anaesthesia in women undergoing emergency Caesarean section because they are at risk of regurgitation and pulmonary aspiration. The force that needs to be applied during cricoid pressure to prevent regurgitation is not known. It depends on the pressure of the oesophageal and gastric contents but these have not been measured in women presenting for emergency Caesarean section. From a study of cadavers we can suggest the amount of cricoid force that prevents regurgitation of liquid at any given oesophageal pressure.1

The purpose of this study was to record oesophageal and gastric pressures and volumes in women presenting for emergency Caesarean section under general anaesthesia after intubation of the trachea and with full neuromuscular block.

Methods and results

The study was approved by the District Ethics Committee. Since the publication of Report on Confidential Enquiries into Maternal Deaths in the UK, in 1994,2 it has been routine practice in our maternity unit to empty the stomach with a large orogastric tube after intubation but before extubation in all emergency Caesarean sections under general anaesthesia. As we planned to use this tube for measurements in this study, Ethics Committee approval was granted to perform the study without patient consent.

We studied emergency Caesarean sections under general anaesthesia over a 2-yr period (1996–1997). Women with multiple pregnancies or polyhydramnios were excluded. After administration of 30 ml of sodium citrate 0.3 mol litre\(^{-1}\), women were positioned supine on the operating table with a 15° firm rubber wedge under the right buttock. They received standard rapid sequence induction with preoxygenation followed by thiopental 4–5 mg kg\(^{-1}\) and succinylcholine 100 mg. Cricoid pressure was used throughout induction and was released after correct placement of the tracheal tube had been confirmed. Anaesthesia was maintained with up to 1.5% isoflurane and 50% nitrous oxide in oxygen. Neuromuscular block was maintained with atracurium 0.4 mg kg\(^{-1}\) and the lungs were ventilated with a tidal volume of 600 ml at a rate necessary to maintain end-tidal carbon dioxide partial pressure at 4.0 kPa.

Gastric and oesophageal pressures were measured via a
undergoing emergency Caesarean section under general anaesthesia (mean (sd) [range])

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (SD) [Range]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>1.58 (5.8) [1.47–1.7]</td>
</tr>
<tr>
<td>Antenatal clinic weight (kg)</td>
<td>62 (12) [47–90]</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>29 [19–40]</td>
</tr>
<tr>
<td>Oesophageal pressure (mm Hg)</td>
<td>7 (4.69) [0–16]</td>
</tr>
<tr>
<td>Gastric pressure (mm Hg)</td>
<td>11 (4.67) [4–19]</td>
</tr>
<tr>
<td>Maximum gastric pressure (mm Hg)</td>
<td>19 (12.26) [6–65]</td>
</tr>
<tr>
<td>Gastric pressure after delivery (mm Hg)</td>
<td>8 (4.44) [0–15]</td>
</tr>
<tr>
<td>Gastric volume (ml)</td>
<td>112 (82.7) [20–350]</td>
</tr>
<tr>
<td>Oesophageal volume (ml)</td>
<td>3 (3.35) [0–10]</td>
</tr>
<tr>
<td>Time since last meal (h)</td>
<td>8 (3.64) [3–15]</td>
</tr>
</tbody>
</table>

Table 1 Patient characteristics and gastric pressures in 20 pregnant women

20-FG double-lumen Salem sump tube, used routinely to empty the stomach during this operation. The smaller lumen (1.0 mm diameter) of the Salem sump tube was connected to a Baxter central venous pressure transducer, with the calibration checked in cm H$_2$O (13.5 cm H$_2$O = 10 mm Hg), and perfused with normal saline at a rate of 3.0 ml h$^{-1}$ thus acting as a pressure manometer. The main lumen of the tube was filled initially with water and plugged. The pressure was displayed on both digital and screen display (Datascope 3000). After tracheal intubation and administration of a non-depolarizing neuromuscular blocker, the pressure transducer was zeroed with the tip of the perfused catheter positioned at the mid-axilla of the patient. The tube was then passed through the mouth into the oesophagus and at this point (30 cm from the teeth) a pressure reading was recorded. The tube was then advanced into the stomach (50 cm from the teeth) and a second pressure reading was recorded. At this point surgery was commenced and gastric pressure readings were recorded on a paper trace during and after delivery of the baby. At the end of surgery, both lumens of the Salem sump tube were opened to air and gastric contents were aspirated and measured with a 50-ml syringe through the main lumen. The Salem sump tube was then withdrawn into the oesophagus (30 cm from the teeth) where the oesophageal contents were aspirated and measured before removing the tube at the end of surgery. The trachea was extubated awake with the patient in the left lateral position.

Twenty pregnant women, median gestation 40 weeks (range 31–40 weeks), were studied over the 2-yr period. All required emergency Caesarean section under general anaesthesia. Of the women studied, 15 were in labour before Caesarean section (mean duration 5 (range 1–12) h); 10 had fetal distress, three failed to progress, one had severe pre-eclampsia and one required Caesarean section for maternal herpes infection. Five women had an antepartum haemorrhage with placenta praevia and were not in labour but were not formally fasted before surgery. Ward policy allows no food but free fluids during labour. None of the women was diabetic. Nine of 20 women were given oral ranitidine 150 mg before anaesthesia. Six women had received opioid analgesia during labour, before surgery (five pethidine, one methadone and two epidural fentanyl).

Oesophageal and gastric pressures and volume of their contents are given in Table 1. All patients had an increase in gastric pressure during delivery; in all but one patient, gastric pressure was less than 31 mm Hg. The exception was a woman with an increase in gastric pressure to 65 mm Hg during fundal pressure. After delivery all but two patients had a decrease in gastric pressure. There was a significant difference between gastric pressures before and after delivery ($P<0.001$, paired $t$ test).

There was no correlation between gastric pressure and gastric volume (Pearson’s correlation coefficient, $r=−0.197$, $P>0.2$). There was no significant difference between gastric volume or gastric pressure in those who had received opioids during labour and those who had not ($P>0.2$, unpaired $t$ test). There was no correlation between gastric volume in relation to fasting duration or duration of labour before surgery.

Discussion

Oesophageal pressure can increase to equal gastric pressure during gastro-oesophageal reflux as the lower oesophageal sphincter relaxes to create a common cavity. The force that needs to be applied to the cricoid cartilage during cricoid pressure to prevent regurgitation depends on the maximum oesophageal pressure during reflux and therefore also on maximum gastric pressure.

Previous studies have measured gastric pressures in fasted patients. La Cour$^4$ studied 51, and Spence, Moir and Finlay$^5$ studied 83 supine patients during general anaesthesia who were not pregnant; both studies found that mean gastric pressure was 5 (range 1–11) mm Hg. La Cour found that during succinylcholine fasciculations, gastric pressure could reach 25 mm Hg.$^4$ Spence, Moir and Finlay$^5$ also studied 31 pregnant women at term while supine during general anaesthesia but did not mention the mode of delivery or whether they were in labour.$^5$ They found a mean gastric pressure of 10 (range 5–13) mm Hg; our results were similar, with a mean gastric pressure of 11 (range 4–19) mm Hg. We can predict that 99% of women undergoing emergency Caesarean section with neuromuscular block are likely to have a gastric pressure of less than 25 mm Hg (mean $\pm$ 3 SD).

A study of 10 cadavers showed that 20 N of force applied to the cricoid cartilage prevented regurgitation of oesophageal fluid at a pressure of 25 mm Hg in all cases and 30 N prevented regurgitation at a pressure of 40 mm Hg in all cases.$^1$ Therefore, 20 N of cricoid pressure is probably sufficient and 30 N is more than sufficient to prevent regurgitation into the pharynx. Anaesthetic assistants can be trained to apply the correct force by practising on weighing scales$^6$ and thus can apply a range of forces of 5 N above or below the target force.$^6$ Therefore, a reasonable recommendation would be to apply 30 N (3 kg). This amount of cricoid pressure is uncomfortable and can cause retching,$^7$ hence cricoid pressure should be applied lightly during induction$^8$ and increased to 30 N after loss of consciousness.
Although gastric pressure increases if coughing, straining or retching occurs during induction of anaesthesia, we did not attempt to record gastric pressure during induction as we do not believe this to be relevant. Cricoid pressure cannot be expected to prevent regurgitation during these manoeuvres as the excessive force that would be necessary could itself cause these problems. The full force can only be tolerated during anaesthesia. If these problems did occur during induction, then regurgitation could result. However, coughing and straining during induction can cause an increase in upper oesophageal sphincter pressure to more than 100 mm Hg which may itself be protective.

During delivery of the baby we found that there was a considerable increase in gastric pressure. In the rare event of failure to intubate the trachea during general anaesthesia, but a need to continue with the anaesthetic, cricoid pressure should be maintained during surgery, although this may be difficult. However, in one patient, we recorded a surge in gastric pressure to 65 mm Hg during fundal pressure which may have been sufficient to cause regurgitation of gastric contents into the pharynx despite cricoid pressure.

Gastric volumes were more than 100 ml in 50% of women. This compares with a study by Stuart and colleagues who compared various acid aspiration prophylactic regimens for emergency Caesarean section and found a median volume of 55 (range 9–360) ml in 120 women receiving sodium citrate prophylaxis. The policy of allowing free oral fluids in our maternity unit may explain our higher volumes. However, there was no correlation between gastric volume and gastric pressure and this is not surprising considering the high compliance of the stomach. Gastric pressure probably relates more to intra-abdominal pressure; the decrease in gastric pressure after delivery would indicate that the high gastric pressures during pregnancy have mainly a mechanical cause. The decrease in gastric pressure after delivery was also observed but not quantified by Spence, Moir and Finlay.

Oesophageal pressure was always positive, probably because positive pressure ventilation was used, but it was always the same or lower than gastric pressure. The volume of oesophageal contents was usually less than 5 ml, but in two women it was 10 ml. In both of these women oesophageal pressure was the same as gastric pressure, possibly indicating a common cavity with the reflux of gastric contents.

In summary, we have measured gastric pressure during emergency Caesarean section under general anaesthesia with neuromuscular block. We recorded a mean gastric pressure of 11 mm Hg and can predict that the pressure should be less than 25 mm Hg in 99% of cases. This has implications for the amount of cricoid pressure required during induction of anaesthesia.

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