RELATIONSHIP BETWEEN LOWER OESOPHAGEAL CONTRACTILITY AND TYPE OF SURGICAL STIMULATION

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SUMMARY
We have studied the effects of two discrete types of surgical stimulation on contractions in the lower oesophagus. Forty-four female patients undergoing either abdominal hysterectomy or varicose vein surgery were anaesthetized using a standard technique. The frequency of spontaneous oesophageal contractions (SLOC) and amplitude of provoked contractions (PLOC) were greater in those patients undergoing hysterectomy. The oesophageal index (OCI), a single index combining both types of contractions, was found also to relate to the nature of the surgical stimulus.

KEY WORDS

The measurement of oesophageal contractions has been proposed as a monitor of adequacy of anaesthesia [1, 2]. There are three discrete types of oesophageal contraction: primary, as initiated by swallowing; secondary, occurring in response to an intraluminal bolus of food, and which may be provoked artificially by inflation of a balloon in the oesophageal lumen; and tertiary contractions which occur spontaneously and serve no propulsive function.

Spontaneous oesophageal contractions are known to relate to stress in awake subjects [3, 4]. Lower oesophageal contractility has been studied during the administration of various concentrations of volatile anaesthetic agents and significant relationships have been demonstrated between minimum alveolar concentration (MAC) and both frequency of spontaneous (or tertiary) and amplitude of provoked (or secondary) contractions [2, 5, 6]. Significant correlations exist also between oesophageal contractility and clinical signs of light anaesthesia [2, 7]. However, it is important to establish that a proposed monitor of anaesthetic depth is affected not only by anaesthetic drugs, but also by surgical stimulation. This study has attempted to identify the differences in contractions during two discrete types of surgical stimulus in patients anaesthetized using a standard technique.

PATIENTS AND METHODS
Following approval of this investigation by the local Ethics and Research committee, 44 female patients (ASA I or II) gave informed consent for the study. Twenty-two were undergoing varicose vein surgery and the same number abdominal hysterectomy. Records were made of age and weight of each patient. No patient was being treated with medication that might interfere with oesophageal contractility.

Anaesthetic technique
In each patient the same anaesthetist conducted the anaesthetic, while a second, who was not involved in the study and who was unable to see the display of the oesophageal contractility monitor, was asked to intervene and increase the concentration of volatile agent if he thought that, clinically, the patient was inadequately anaesthetized; in no patient was this found to be necessary. All patients were premedicated with


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temazepam 20 mg 1 h before proposed surgery. A 14- or 16-gauge cannula was inserted into a vein in the dorsum of the hand under local anaesthesia. Anaesthesia was induced with thiopentone 5 mg kg\(^{-1}\) and morphine 10 mg. Neuromuscular block was achieved using vecuronium 0.1 mg kg\(^{-1}\) and the trachea was intubated.

The lungs were ventilated with 70% nitrous oxide in oxygen and isoflurane was added to the inspired mixture to maintain an end-tidal concentration of 0.5%, measured using the Datex Capnomac. Increments of the myoneural blocker (0.02 mg kg\(^{-1}\)) were administered on return of the second twitch of train-of-four stimulation of the ulnar nerve. In all patients the fresh gas flow was adjusted to maintain the end-tidal concentration of carbon dioxide at 4.0–5.0%. All patients were positioned with 15° of head-down tilt during surgery.

**Oesophageal monitoring**

Following incubation of the trachea, an oesophageal probe (which resembles a large-bore stomach tube) was inserted such that its distal end was positioned in the lower one-third of the oesophagus. The probe incorporates two balloons: the upper balloon was used to provoke secondary contractions by intermittent inflation with air; the distal balloon was filled with water and detected changes in intraluminal pressure corresponding to any oesophageal activity. The probe was connected via a pressure transducer to the Lectron 301 oesophageal contractility monitor which displayed oesophageal activity on an oscilloscope screen. A simultaneous copy was produced on a two-channel chart recorder which records also the type of contraction (provoked or spontaneous).

At the end of the procedure, a printed record of the nature and timing of every contraction was produced. Data for analysis were taken directly from this printout, thus eliminating any bias in interpretation of the original trace.

The lower oesophageal contractility index (LOCI) was calculated from the formula [8]:

\[
\text{LOCI} = \text{PLOC}(\text{mm Hg}) + 70 \times \text{SLOC}(\text{min}^{-1})
\]

Data were analysed using Student's unpaired \(t\) test, Wilcoxon rank sum test or Wilcoxon signed rank test, as appropriate.

**RESULTS**

Analysis of patient data demonstrated no significant differences between the groups in respect of age, weight or steady state end-tidal concentration of carbon dioxide (table I). Spontaneous contraction frequency and provoked contraction amplitude were analysed in 5-min epochs from the time of incision.

Figure 1 shows the frequency of spontaneous oesophageal contractions in the period before in-
TABLE I. Mean (SEM) values for data of patients undergoing varicose vein surgery (VV) or hysterectomy (Hy)

<table>
<thead>
<tr>
<th></th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>End-tidal CO₂ (%)</th>
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</thead>
<tbody>
<tr>
<td>VV</td>
<td>47.4(2.7)</td>
<td>64.3(2.3)</td>
<td>4.51(0.069)</td>
</tr>
<tr>
<td>Hy</td>
<td>43.9(1.8)</td>
<td>65.6(2.6)</td>
<td>4.44(0.068)</td>
</tr>
</tbody>
</table>

cision and in 5-min epochs following incision. All the values after incision were significantly greater ($P < 0.005$) in patients undergoing hysterectomy than in those undergoing vein surgery. There was a small but insignificant difference between the initial values. Changes relative to the baseline values before incision were significantly different.

Fig. 2. Mean (SEM) change of SLOC frequency from the pre-incision values. Differences significant ($P < 0.05$) except at 5 and 45 min.

Fig. 3. Mean (SEM) PLOC amplitude in the period before, and in 5-min epochs after incision. Differences significant for all post-incision values ($P < 0.005$ up to 25 min; $P < 0.02$ 30–45 min).
For provoked oesophageal contractions, mean amplitude values for the two groups were significantly different in all epochs following the time of incision (fig. 3).

The lower oesophageal contractility index (LOCI) was calculated for each epoch in patients for varicose vein surgery and hysterectomy. The LOCI was significantly greater at all times in those patients undergoing hysterectomy (fig. 4).

None of the patients had spontaneous recall of intraoperative events when questioned on the first day after operation.

DISCUSSION

This study has demonstrated differences in lower oesophageal activity between patients anaesthetized using the same technique for abdominal hysterectomy or varicose vein surgery. We have assumed that the degree of surgical stimulation was greater during hysterectomy than during varicose vein surgery. Most anaesthetists would agree that intra-abdominal procedures result in greater stimulation than do peripheral operations. However, we are unable to prove that stimulation was greater in that it would be more likely to result in awareness [9].

Differences in adrenaline, noradrenaline and cortisol hormonal responses have been demonstrated between severe, moderate and minimal stress surgical procedures [10]; hysterectomy was considered a “moderate stress” procedure and varicose vein surgery minimally stressful according to the classification used by the authors of that report. It is not surprising that such a difference should exist, as pelvic surgery causes stimulation of autonomic afferent nerves in addition to somatic pain fibres from the skin and abdominal wall.

The publication of data comparing oesophageal contractility during discrete surgical procedures [11] stimulated a retrospective review of the mean LOCI of 43 patients undergoing eight different operations [12]. Whilst failing to achieve statistical significance, the value of LOCI for those patients undergoing cholecystectomy was found to be 76 compared with an LOCI of 29 for those undergoing hernia repair.

Previous studies have demonstrated a relationship between lower oesophageal contractility and MAC for halothane [2, 5] and isoflurane [6] during anaesthesia for a variety of surgical procedures. Comparisons have been made also of oesophageal contractility with clinical signs of light anaesthesia such as tachycardia, increase in arterial pressure, lachrymation and increased sudomotor activity, and statistically significant correlations exist [2, 7]. An increase in oesophageal activity in response to surgical stimulation has also been noted [2], but no previous controlled study to relate the two has been performed.
For logistical reasons, it was not possible in the present study to establish steady state conditions of anaesthesia before surgery started. The initial reduction in oesophageal contractility during operation in patients who underwent varicose vein surgery was probably caused by the increasing brain concentrations of morphine and equilibrium of isoflurane concentrations between blood and brain while a steady state was achieved. We believe that the tendency of these increasing drug concentrations to reduce oesophageal contractility was countered in the hysterectomy patients by a greater degree of afferent neural activity.

The lower oesophageal contractility index (LOCI) is a derived value for oesophageal activity; the index was intended to incorporate information regarding both spontaneous and provoked activity in a ratio which ascribes equal numerical weight to each value [9]. The mean SLOC frequency and PLOC amplitude during the steady state administration of 1 MAC of halothane are 0.5 min⁻¹ and 35 mm Hg, respectively and therefore, in the calculation of LOCI, the value of SLOC frequency is multiplied by 70 before addition to the PLOC amplitude value. The combinations of these two aspects of oesophageal contractility may improve the sensitivity of this form of monitoring.

In common with previous work, the present study has highlighted the variation in oesophageal activity both within and between patients, in a manner which could prevent the information obtained from being predictive of inadequate anaesthesia for each individual. Consequently, oesophageal monitoring falls short of providing the "ideal" index of anaesthetic depth.

The concept of adequacy of anaesthesia is of a balance between CNS depression caused by administration of anaesthetic drug and arousal caused by surgical stimulation. Any proposed monitor is therefore required to reflect both influences. It has been shown that the effect of anaesthesia upon the amplitude of cortical waves on the auditory evoked response (AER) is reversed partially by surgical stimulation in some patients [13]. However, AER information takes several minutes to produce and, even using a rolling average, the data obtained do not reflect the current cerebral state. Oesophageal contractility is shown to relate to both anaesthetic agents and surgical stimuli, and such a delay is not a feature of the spontaneous contractions.

Other important elements required of the theoretical ideal monitor of anaesthetic adequacy are that it be non-invasive, portable, inexpensive, reliable, and easy to use and interpret. The oesophageal contractility monitor possesses some of these desirable features but, as with all proposed monitors of anaesthetic depth, its evaluation is made difficult by the lack of a "gold standard" for comparison. In the absence of other standards, any form of monitoring must be studied under conditions known to reflect adequacy of anaesthesia.

We conclude that oesophageal contractility during anaesthesia is related certainly to the nature, and possibly to the intensity, of surgical stimulation.

REFERENCES