lower oesophageal contractility and detection of awareness during anaesthesia

p. a. isaac and m. rosen

summary

we have investigated the value of lower oesophageal contractility (loc) in detecting awareness during anaesthesia in 20 human volunteer patients. loc was measured either with subjects awake or after induction with propofol, during induction with propofol, and then as consciousness returned. statistically significant changes were observed in the frequency of spontaneous contractions, peak and mean amplitude of spontaneous and provoked contractions, and the oesophageal contractility index as subjects lost consciousness and also as it was regained. the differences in loc which occurred when subjects were conscious and unconscious support the view that loc is related to the depth of anaesthesia, but its unreliability at the interface between consciousness and unconsciousness prevents selective detection of awareness, although the response in the presence of painful stimuli has not been tested.

key words

anaesthesia: depth. gastrointestinal tract: oesophageal contractility.

awareness during anaesthesia has been defined by wilson [1] as “the ability of patients to recall, with or without prompting, any event occurring during anaesthesia.” however, it is possible for a patient to be aware of his or her surgery during an anaesthetic but not recall the awareness after operation if the anaesthesia is subsequently deepened [2]. previous studies have reported a wide range of incidences of awareness depending upon the method of detection [3], up to 40% using postoperative hypnosis [4]. more recently, using the isolated forearm technique for detection [5], russell described a 44% incidence of “wakefulness” in patients anaesthetized with nitrous oxide and fentanyl. this is similar to the 46% incidence reported by shultetus and colleagues [6], using the same detection method but a different anaesthetic technique.

many methods of assessing depth of anaesthesia have been investigated, including the cerebral function analysing monitor [7], power spectrum analysis [8], frontal EEG and frontal EMG [9], the electroretinogram [10] and changes in skin electrical conductance [11]. Recently, auditory evoked potentials have been reported to be accurate in the detection of inadequate anaesthesia allowing awareness, in a study using methodology similar to that described below [12]. the measurement of lower oesophageal contractility (loc) has been suggested as a means of detecting episodes of too light and too deep anaesthesia [13] and has been used to provide feedback control of an i.v. anaesthetic infusion system [14]. as the occurrence of awareness during anaesthesia, with or without recall, can be considered to be a potential consequence of inadequate anaesthesia, we have investigated the value of loc in detecting actual awareness by examining loc in human volunteers as they lost consciousness under the influence of propofol, and regained consciousness.

patients and methods

patients about to undergo intermediate or major surgery gave informed consent for the study, which was approved by the district ethics


*present address, for correspondence: department of anaesthesiology, U.T. southwestern medical center, 5323 harry hines boulevard, Dallas, Texas 75235, U.S.A.

†an abstract of this work was presented to the anaesthetic research society, November 1987.
Committee. Patients were informed that they would awaken transiently from anaesthesia shortly after induction, but before surgery had commenced, and would then have anaesthesia induced once again. Patients with a history of oesophago-gastric disease and those taking medication with anticholinergic actions were excluded.

LOC was measured by passing an oesophageal probe with a distal water-filled sensing balloon and a proximal provoking balloon into the lower oesophagus as described elsewhere [13]. This system was connected via a pressure transducer to a Lectron 301 oesophageal monitor (Antec Systems Ltd, Oxford).

Patients sucked an amethocaine lozenge (60 mg) and had the pharynx sprayed with 10% lignocaine from a metered dose spray; subsequently they attempted to swallow the probe whilst awake. A small bolus (up to 10 mg) of i.v. diazepam was given to any patient who had difficulty in swallowing the probe. A pilot study had shown that pharyngeal local anaesthesia or a small dose of diazepam did not significantly affect LOC [personal observations]. If the patient was still unable to swallow the probe, an induction dose of propofol 2.5 mg kg\(^{-1}\) was administered and the probe was introduced. When the patient was settled with the probe in place and was awake (had not received propofol to facilitate insertion of the probe), an infusion of propofol, set initially at an average rate of 15 mg kg\(^{-1}\) h\(^{-1}\) and adjusted to produce induction of anaesthesia over approximately 5 min, was started while the patient breathed oxygen via a Mapleson A circuit. If propofol had been used to introduce the probe, the patient was allowed to awaken with the probe in place. After an interval of approximately 2–3 min, anaesthesia was re-induced with an infusion of propofol.

At 30-s intervals, each subject’s conscious level was assessed during induction of, and emergence from, anaesthesia by observing the subject’s response to a command to squeeze the investigator’s hand. The time at which hand squeezing appeared or disappeared was noted. This was defined as the “cross-over point.”

When light anaesthesia had been induced, as judged by loss of the hand squeezing response, the infusion was discontinued and the patient was allowed to regain consciousness. The point at which this was judged to have occurred was when the hand squeezing response returned. All analyses of recordings were made in the 2-min periods before and after the cross-over point, and compared using the Wilcoxon rank sum test. The study ended at this point and anaesthesia was re-induced for surgery. All subjects were visited on the day following surgery and enquiry made for recall of induction of anaesthesia and occurrence of dreaming during anaesthesia.

RESULTS

Twenty subjects were studied (mean (SD) age 49.4 (13.8) yr, weight 69.0 (16.2) kg and height 167.1 (9.6) cm). Fourteen patients received diazepam...
LOC AND AWARENESS

Fig. 2. Change in peak amplitude of provoked contractions as patients lost consciousness (left) and regained consciousness (right). Each line represents an individual subject, except where more than one subject is indicated by number. ▲ = Subjects in whom contractions were present in the awake phase only; △ = subject in whom contractions were present in the unconscious phase only.

Fig. 3. Change in mean amplitude of provoked contractions as patients lost consciousness (left) and regained consciousness (right). Each line represents an individual subject, except where more than one subject is indicated by number. ▲ = Subjects in whom contractions were present in the awake phase only; △ = subject in whom contractions were present in the unconscious phase only.

and eight patients received a bolus of propofol to enable insertion of the probe. LOC recordings were made in 17 subjects as consciousness was lost, and in 14 subjects as it was regained. In three patients, recordings were not made as consciousness was lost because of a probe leak in one patient and inadequate time before surgery in the other two. In six patients, recordings were not made as consciousness was regained because of probes leaking in two patients, coughing in two patients and shortage of time in two.

Measurements made from the LOC recordings included frequency, mean and peak amplitude of all spontaneous lower oesophageal contractions (SLOC) and the mean and peak amplitude of all provoked lower oesophageal contractions (PLOC) in each 2-min period. In addition, oesophageal contractility index (OCI) [15] was calculated. Figures 1–4 show the spontaneous frequency, provoked amplitude and OCI for each patient before and after the cross-over period—that is, as patients lost consciousness and regained it. The
changes in mean contraction height and frequency and the mean OCI of the subjects in the conscious and unconscious states as the subjects regained consciousness are compared in table I, and changes as the subjects lost consciousness in table II.

Before and after the cross-over period, there were statistically significant changes in the mean values of all variables. However, for some subjects the changes were in a direction opposite to those in other patients, or of such small magnitude as to be clinically insignificant. For example, figure 1 shows a slight increase in frequency of contraction in two subjects as they became unconscious, and

**TABLE I. Mean (sd) changes in contraction frequency (contractions per minute), amplitude (mm Hg) and oesophageal contractility index (OCI) as subjects lost consciousness. n = 17. SLOC = spontaneous lower oesophageal contractions; PLOC = provoked lower oesophageal contractions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conscious</th>
<th>Unconscious</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOC frequency</td>
<td>3.4 (3.6)</td>
<td>0.7 (1.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>SLOC peak amplitude</td>
<td>47 (33)</td>
<td>21 (34)</td>
<td>0.007</td>
</tr>
<tr>
<td>SLOC mean amplitude</td>
<td>25 (17)</td>
<td>11 (18)</td>
<td>0.005</td>
</tr>
<tr>
<td>PLOC peak amplitude</td>
<td>27 (25)</td>
<td>14 (25)</td>
<td>0.006</td>
</tr>
<tr>
<td>PLOC mean amplitude</td>
<td>21 (18)</td>
<td>15 (24)</td>
<td>0.042</td>
</tr>
<tr>
<td>OCI</td>
<td>257 (254)</td>
<td>73 (88)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**TABLE II. Mean (sd) changes in contraction frequency (contractions per minute), amplitude (mm Hg) and oesophageal contractility index (OCI) as subjects regained consciousness. n = 14. SLOC = spontaneous lower oesophageal contractions; PLOC = provoked lower oesophageal contractions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unconscious</th>
<th>Conscious</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOC frequency</td>
<td>0.7 (1.5)</td>
<td>2.3 (3.6)</td>
<td>0.001</td>
</tr>
<tr>
<td>SLOC peak amplitude</td>
<td>15.7 (24)</td>
<td>36 (30)</td>
<td>0.009</td>
</tr>
<tr>
<td>SLOC mean amplitude</td>
<td>15 (26)</td>
<td>25 (26)</td>
<td>0.043</td>
</tr>
<tr>
<td>PLOC peak amplitude</td>
<td>16 (27)</td>
<td>27 (31)</td>
<td>0.006</td>
</tr>
<tr>
<td>PLOC mean amplitude</td>
<td>15 (26)</td>
<td>26 (31)</td>
<td>0.005</td>
</tr>
<tr>
<td>OCI</td>
<td>66 (110)</td>
<td>180 (252)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**FIG. 4. Change in oesophageal contractility index as patients lost consciousness (left) and regained consciousness (right). Each line represents an individual subject, except where more than one subject is indicated by number.**
in both directions of change of consciousness there were subjects in whom no difference in frequency was detected. However, the general trend observed was for contractions to decrease in frequency as consciousness was lost and increase as consciousness was regained. No particular frequency corresponded to any particular conscious level. The variations between individual subjects were more apparent when changes in provoked contractions were examined (fig. 2, 3).

At the postoperative visits no patient had recall of induction of anaesthesia or experienced dreams during anaesthesia and surgery.

DISCUSSION

The design of this study allowed the conscious state of the patient to be altered with the use of anaesthetic drugs and an end-point to be identified, but it does have several disadvantages.

First, the point at which the conscious patient becomes unconscious cannot be determined, because these terms are not precise and the i.v. induction of anaesthesia involves continuous and gradual changes. The response to a command (hand squeezing) was used as a readily detectable and normally accepted sign of return of consciousness, and the lack of a response as a sign of loss of consciousness. We accept that the change in conscious level may have occurred shortly before the response was lost or appeared and did not represent the exact point at which consciousness was lost or regained, but an attempt to elicit the response was made at frequent intervals in all subjects. Therefore the cross-over point represents the same stage in each patient. In the presence of a surgical stimulus, the change in response to command might have occurred at a different stage. However, it was not possible to study this because it would have been unethical intentionally to allow patients to awaken in the presence of a painful stimulus solely for the purposes of this study.

Second, the level of anaesthesia induced was necessarily light to allow rapid return of consciousness. Therefore, the changes in LOC may not have been as large as if the patient had awakened from a deeper plane of anaesthesia.

Third, patients were not awakening either to the presence of a painful surgical stimulus or to the realization that they were awake and paralysed. Notwithstanding these inherent problems in our methodology, we believe this is a useful model for the study of the physiological changes accompanying awareness under anaesthesia.

Evans, Davies and Wise [13], in common with other workers [16–18] have described a relationship between depth of anaesthesia and frequency of spontaneous contractions and amplitude of provoked contractions, but not amplitude of spontaneous contractions. However, we have demonstrated a statistically significant increase in amplitude of spontaneous contractions in the awake compared with the unconscious phase. At these light stages of anaesthesia in the unstimulated patient, it appears that the "all or none" response of SLOC contractions described by Evans, Davies and Wise [19] is not operative, and a graded response may be seen, although it is not clear from our results if this is a clinically significant finding or a consequence of artificial stimulus-free study conditions.

In some patients the changes in frequency and amplitude of contractions observed in the awake and unconscious phases were minor; occasionally there was a decrease in frequency or amplitude when an increase would have been expected, and vice versa. So, although the changes were statistically different when the data for all patients were pooled, overall the changes were not clinically significant for the group.

Previous studies have drawn attention to the limitations of LOC in determining depth of anaesthesia in an individual patient. Aitkenhead, Lin and Thomas [16] showed that, while there appeared to be a gradual increase in SLOC which preceded the clinical signs, SLOC still occurred in some patients during apparently inadequate anaesthesia. Similarly, the likelihood of increased PLOC amplitude increased as anaesthesia lightened, but PLOC amplitude would not have been accurate in predicting inadequate anaesthesia in most patients. Schwieger and colleagues [20] demonstrated that, during fentanyl anaesthesia, SLOC rate was of limited value in determining adequacy of anaesthesia in nearly 50% of the patients studied. Thomas and Aitkenhead [18] observed that the intensity of surgical stimulation may be important in determining the level of oesophageal activity.

The patients’ lack of recall of induction of anaesthesia and absence of dreaming may have been a result of the administration of diazepam to some patients. Also, after the study period all patients underwent intermediate to major surgery, and this may be a more important factor.
We conclude that, although there was an overall trend towards an increase in frequency and amplitude of contractions with an increase in conscious level at the “very light” end of the anaesthetic spectrum, the relationship was not sufficiently reliable for the detection of consciousness. With our model, LOC could not be demonstrated to be useful in determining when consciousness had returned to anaesthetized patients.

REFERENCES