undefined movements is the same as if no neuromuscular blocking agents were involved – deepen anaesthesia.

Declaration of interest

R.D.S. is a Board member of the BJA.

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Anaesthesia for awake craniotomy

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Groucho Marx, who famously claimed that 'military intelligence' was a contradiction in terms, would quite likely express similar sentiments about the title of this editorial, were he still alive. What we really mean with this phrase, is 'anaesthetic management' of a patient who is required to be conscious and co-operative during some period of time during a brain tumour resection procedure. A wide range of anaesthetic management strategies are used, but most techniques involve sedation or general anaesthesia before and after mapping, and are probably better referred to as '*craniotomy with intraoperative awakening*.'

Awake craniotomy is growing in popularity among neurosurgeons, to the extent that it has been suggested that it should be used for all brain tumor excisions.[1] Readers unfamiliar with this field will naturally be asking themselves why it is necessary for a patient to be conscious during the procedure, so we will first deal with this issue. For most axial or intrinsic brain tumours, surgical excision is not curative. Low grade gliomas, for example, have no distinct boundaries with the surrounding brain parenchyma. By the time the tumour is symptomatic, cells will have migrated widely, making a complete excision neither possible nor feasible. The aim of the excision is to reduce the bulk of the tumour, relieve symptoms, buy time and optimize the efficacy of chemo- or radiotherapy. An optimal excision is one that results in maximal removal of tumour mass but minimal functional consequences. In particular, neurological deficits arising from excision or injury of areas essential to speech and motor control functions can be particularly devastating, and for this reason a tumour in an eloquent region is a common indication for awake craniotomy.

To limit the chances of an iatrogenic neurological deficit, the surgeon needs to know which areas of the brain in the vicinity of the tumour serve important functions and should thus not be removed. He or she thus needs a map that correlates anatomical structure/location with function, so-called functional mapping, to assist achievement of an optimal balance between completeness of tumour resection and preservation of function.

Students of medicine will all be familiar with the time-honoured Brodmann system, which divides the cerebral cortex into 52 areas on the basis of cytoarchitecture.[2] Although many of these areas have been associated with specific cognitive functions – often on the basis of lesion studies – there remains considerable heterogeneity between individuals. Thus, this classification system is inadequate to guide the surgeon, and more information is needed.

Currently, the gold standard technique for mapping involves direct cortical electrical stimulation while the patient is awake and able to attempt to perform a relevant task, to determine if the stimulus disrupts execution of the task. Facilitation of this technique is the goal of awake craniotomy. But are there any possibilities for functional mapping that do not require a craniotomy AND a conscious patient? Is it possible to gather some or even all of the information 'non-invasively' before the patient undergoes their surgery, or to gather it during a craniotomy but with the patient under general anaesthesia?

At present, the most common techniques used preoperatively to analyse functionality of peri-tumoral brain areas are functional MRI (fMRI) and Diffusion Tensor Imaging (DTI). By providing a map of possible eloquent regions these techniques can help inform decisions on the surgical approach and the necessary vigilance required when resecting tissue at the edge of the tumor. While fMRI provides a measure of cortical activity, DTI provides a map of the important subcortical fiber pathways connecting distant brain areas. However, these techniques are inherently unreliable for two reasons. Firstly they do not measure functionality directly. Instead fMRI registers small regional changes in the so-called blood oxygenation level dependent (BOLD) signal. The BOLD signal is generated by inhomogeneities in the magnetic field, arising from changes in the regional concentration of deoxygenated haemoglobin, in areas involved in performance of a particular cognitive task (oxy- and deoxy-haemoglobin have different magnetic properties).[3] DTI does not assess function but instead maps white matter structures that are assumed to be functional. Secondly, changes in the brain regions surrounding the tumour as a result of oedema or mass effect, may reduce the sensitivity of these techniques. For both reasons, these preoperative techniques cannot be totally relied upon to inform decisions to resect or not resect an area of tissue.

Navigated repetitive transcranial magnetic stimulation (rTMS) is an alternative preoperative technique that may circumvent these problems.[4] It may be able to map language and motor functionality directly, and although it is becoming increasingly popular, its utility is limited by the fact that the mapping is limited to the cortex. An important advantage of awake surgery is that cortical and sub-cortical mapping is possible.

Perioperative stimulation mapping is regarded to be gold standard when a means of functional guidance during surgery is necessary. Whether or not the patient needs to be awake for perioperative mapping depends on the location of the tumor and the experience of the team. Although most patients can be guided through an awake procedure without much anxiety and most will later admit that the difficulties were less severe than anticipated,[5] one cannot deny the burden of such a procedure for the patient. With good teamwork, sensible choice of anaesthetic agent, and careful management of anesthetic depth, motor and sensory mapping can be performed reliably with a patient who is not awake, by measuring motor evoked and somatosensory evoked potentials (MEPs and SSEPs).[6] Advantages of the latter technique are the fact that the patient may be spared the experience of being operated upon while awake, and that the mapping is independent of patient cooperation and effort.

For language mapping though, awake surgery remains indispensable. Obviously, a further advantage of awake surgery is that other modalities can be mapped. In addition to language, not only motor and sensory functions, but also visual fields and even some higher cognitive functions can be mapped. In practice then, when more than motor and sensory mapping is required, an awake procedure seems the logical choice. When only motor and/or sensory mapping are needed, team preference and experience comes into play. In that case, mapping under general anaesthesia is feasible if an experienced multi-disciplinary team is available.

The anaesthetic management of patients undergoing awake resection of brain tumors has been extensively reviewed in the last 10 yr.[7–13] Many different anaesthetic approaches have been suggested. They differ mainly in the suggested drugs and how to deliver them, and in airway management (Fig. 1). Experienced neuroanaesthetists have usually developed a preferred technique and believe their own approach to be the safest and the best.

A detailed discussion of the possible options is beyond the remit of this editorial. We will instead briefly mention some of the important issues and options. An important first step is adequate preoperative patient preparation.[14] During surgery it is especially important to ensure comfort and haemodynamic stability during painful phases (skull pin placement, the craniotomy itself and dural opening). Local anaesthesia is the cornerstone of any awake craniotomy technique, and is typically provided by means of a scalp block, which when performed well with agents such as bupivacaine, levobupivacaine or ropivacaine, can provide good and safe analgesia for eight h or longer.[15 16]

The most major choice facing the anaesthetist is whether the phases before and after mapping should be performed under local anaesthesia only, sedation, or general anaesthesia. Important goals are to ensure that the patient is comfortable, awake and co-operative during the mapping phase, to facilitate acquisition of reliable neurophysiological monitoring signals, and to ensure a soft and slack brain during resection.

Some authors advocate that for the first phase (i.e. before the start of mapping), general anaesthesia, with intermittent positive ventilation via a laryngeal mask airway (LMA) is the best option, as it avoids the risks of over-sedation and hypertension.[7 17 18] A propofol-remifentanil technique can facilitate adequate mechanical ventilation, a smooth but fast transition to the awake state, and removal of the LMA once airway reflexes have returned but before coughing occurs.[19] There are many proponents of other techniques, such as mild or deep sedation, before and after mapping. The group of Kofke and colleagues[20] recently published the results of their specific technique involving deep sedation and nasal airways.

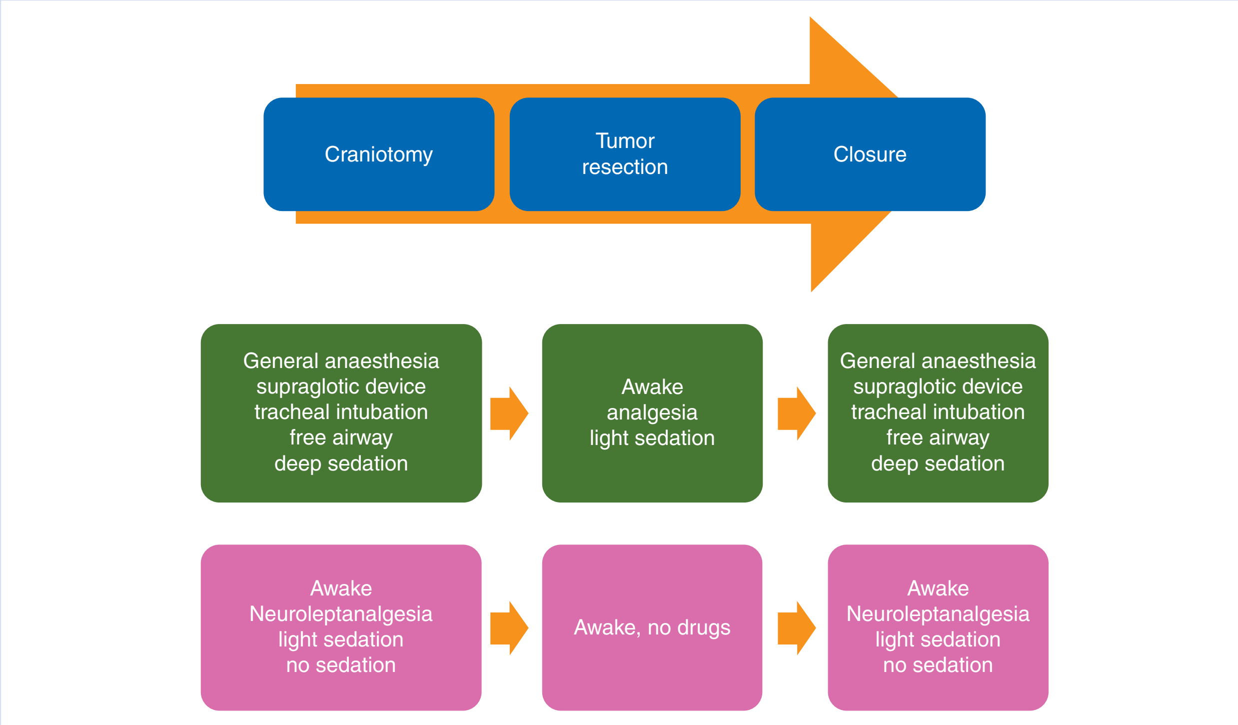

Fig 1 Schematic illustration of the stages of an awake craniotomy, and the main associated anaesthetic management options.

The last phase of an awake craniotomy (haemostasis, dural, skull and skin closure) can also be uncomfortable for patients. By then, they will have been lying immobile for some time, with resultant musculoskeletal discomfort, and at the same time, the local block may sometimes be less effective, particularly during skin closure. Again, the anaesthetist faces the choice between sedation, general anaesthesia or no sedation or anaesthesia. Induction of general anaesthesia at this stage requires experience and expertize, particularly with airway management – LMA insertion is often preferred - as tracheal intubation is challenging in these patients who are usually in a right lateral position, with the head clamped, and in an unfavourable position for laryngoscopy.

For techniques involving sedation or anaesthesia, a wide range of drug choices and combinations have been proposed. These range from neuroleptanaesthesia (droperidol and alfentanil),[21] propofol-fentanyl,[22] propofol-remifentanil for intermittent general anaesthesia or sedation[7 18 19] to sedation/analgesia with dexmedetomidine.[23–25] When possible, it is best to use sedative and analgesic drugs with fast onset and offset of action and ideally minimal cardio-respiratory depression. While propofol and remifentanil have close to ideal pharmacokinetic properties, they do have some undesirable adverse effects, including dose-related respiratory depression. Skill and experience is required to use this combination safely.

The use of target controlled infusion (TCI) technology for propofol and remifentanil administration has been suggested, as it can facilitate accurate and fine titration according to individual anaesthetic requirements.[18 19 26] TCI is a safe technology[27 28] that has been shown in other areas of practice to facilitate haemodynamic and respiratory stability.[29 30] Likewise, despite all the known limitations, EEG-based monitors of hypnosis may also be useful tools, as they provide a measure of the clinical effects of the drugs and can be used to guide drug dosing and improve the speed and quality of intra-operative awakening.[19 31–33]

Dexmedetomidine is an α2 agonist that has only recently become available in Europe. It has an unusual pharmacodynamic profile, providing rousable, sleep-like sedation, some analgesia, and maintained respiratory drive. These features, coupled with reasonably rapid pharmacokinetics are favourable for conscious sedation before and after mapping.[34]

There are many reasons for the considerable variability in anaesthetic techniques used for awake craniotomy procedures around the world. Among them are the differences in patient selection, local experience and the plethora of other factors that determine the expected duration of the operation, no doubt play an important role. While it is surprising how long some patients can remain coherent and co-operative during the awake phase, there are limits to the powers of human endurance during such a stressful experience. Thus, the expected duration of surgery is an important practical consideration. If the overall procedure is expected to last much more than four h, then the patient is probably better served by an 'asleep-awake-asleep' technique. While we have no scientific evidence for this, our experience is that, during long procedures, patients are able to co-operate for longer during the awake phase if they are unconscious during the preparatory phases.

Techniques involving conscious sedation instead of general anaesthesia seem better suited for awake craniotomies that are likely to last less than four h; but as with most aspects of awake craniotomy, until recently, no studies have rigorously compared different techniques. The results of the study published this month by Goettel and colleagues[35] from the Toronto Western Hospital, form a welcome and overdue addition to the scientific literature. Their randomized controlled trial compared two techniques commonly used for conscious sedation – infusions of propofol and remifentanil, vs infusions of dexmedetomidine. In both groups a fentanyl bolus was administered, the assigned drug regimen started, and local anaesthesia performed, before placement of the pins of the head holder. Before and after mapping, sedation was titrated to a modified OAA/S score of 2–4. Pain was managed by an increase in the dexmedetomidine or remifentanil infusion rate, and if that failed, a fentanyl bolus. Likewise, inadequate sedation was managed with an increase in the dexmedetomidine or remifentanil infusion rate, and if that failed, a propofol bolus. In the propofol-remifentanil group, propofol was stopped, and remifentanil infusion rate decreased, 10 min before mapping. In the dexmedetomidine group, the infusion rate was decreased to 0.1–0.4 mcg kg^{-1} h^{-1} 10 min before mapping.

The findings of the study were that the ability to perform intra-operative mapping (primary outcome) was similar between the groups. Although sedation levels were also similar, in keeping with the known pharmacodynamics of the drugs, heart rates were lower in the dexemetomidine group, whereas adverse respiratory events were more common in the propofol-remifentanil group. Although the difference was not statistically significant, it is worth noting that three patients in the dexmedetomidine group had on-table seizures, as opposed to none in the propofol-remifentanil group.

While we commend the authors for their valuable work, it should be remembered that the results apply to a quite specific set of circumstances. In particular, the median procedure time was a mere 121 min. This means that the time period during which sedation was required was short. This is particularly important with dexmedetomidine, as it does accumulate to some extent,[36 37] so that longer durations of infusion will result in a slower return to normal function when the infusion is stopped. Furthermore, patients also only spent two h on the PACU before being discharged to the ward or day surgery unit, and 58% of them went home the same day! From this, it is also reasonable to conclude that, although not explicitly stated, patients undergoing awake craniotomy are likely to be carefully selected, on the basis of patient history and characteristics, the likely extent and duration of brain mapping required, and the likely ease of excision of the tumour.

Strictly speaking then, the current findings only apply to a setting in which good local anaesthesia is applied, and in which local expertize and patient selection permit or require only a short period of sedation, and an even shorter 'awake' period. To know whether the same conclusions apply to conscious sedation for longer time periods, and/or for a longer awake phase, further research is necessary.

In summary then, a wide range of anaesthetic management techniques are available for the care of patients undergoing awake craniotomy. The choice of technique used should be based on a number of factors, not least of which is the local expertize and experience. In many respects the oft-given advice – 'use what works well in your hands' – applies. The article by Goettel[8] is useful for those considering using a sedation-awake-sedation technique, for procedures unlikely to last more than a few h. At the very least, it has shown, in a scientifically rigorous way, equivalence between a propofol-remifentanil-based and a dexmedetomidine-based technique.

Declaration of interest

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Platelet function in paediatric cardiac surgery

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Impaired platelet function is a known risk factor for severe bleeding in adult cardiac surgery.[1–4] In this setting, a poor platelet function after cardiac surgery with cardiopulmonary bypass (CPB) results from a combination of the effects of preoperative administration of anti-platelet agents (namely, those inhibiting the platelet receptor P_2Y_{12}) and intraoperative platelet activation and destruction. The use of platelet function tests (PFT) is gaining more and more evidence in the prevention and diagnosis of platelet dysfunction before and after cardiac surgery.[5–7]

In this issue of the British Journal of Anaesthesia, Romlin and associates[8] present an interesting study focused on different techniques of platelet function monitoring during and after cardiac surgery, with CPB in paediatric (newborns to 7.5 yr old) patients. Platelet function measurement was achieved with multi-electrode aggregometry (MEA) and a visco-elastic test (VET), having the MEA as reference test. They found that the clot formation time and clot firmness at the VET were able to identify platelet dysfunction on CPB, but not after surgery. The study has some limitations, the major ones being the low sample size (which did not allow to search for associations between platelet function and postoperative bleeding), the non-specific value of clot firmness as a marker of platelet function (as a result of fibrinogen concentrations and factor XIII contribution), and the heterogeneous age of the patients (ranging from neonates to children). The finding that a prolonged clot formation time and low maximum clot firmness result in a greater transfusion requirement is clinically relevant; however, as the authors recognize, this pattern of VET is inclusive of other non-platelet function-related factors which may lead to bleeding, namely thrombin generation and fibrinogen concentrations. However, this study has the merit to address a poorly-defined issue such as the role of PFT in the setting of paediatric cardiac surgery.

There are few studies exploring the role of PFT in this specific environment. Recently, Zubair and associates found an association between a low preoperative platelet function and blood product transfusions.[9] A decreased platelet count and function after cardiac surgery was already observed by other authors.[10 11] However, there are studies showing opposite results, with an increased platelet activity,[12] and a study even concluded that cyanotic patients have a preoperative platelet function more