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General review

Operating environment for awake brain surgery – Choice of tests

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ABSTRACT

Introduction. – The indication for awake brain surgery depends on a prerequisite, i.e. recognition that the brain area concerned is truly eloquent, and identification of one or more functions that must be preserved. These functions are determined preoperatively in collaboration with the patient, and neuropsychological tests considered to be the most relevant are performed in the operating room according to each team's technical preferences.
Operating environment. – The neurosurgeon must choose transfer equipment considered to be relevant. Although a minimal technological environment is an option, a surgical team with great human wealth is essential, composed of specialized personnel with complementary skills.
Choice and implementation of intraoperative tests. – The choice of intraoperative tests, which can be relatively simple for certain primary functions, can be much more difficult for high-level cognitive functions. No consensus has been reached concerning these tests, which must therefore be selected on an individual basis. Intraoperative testing must be based on preoperative multidisciplinary decisions made jointly by the neurosurgeon, neurologist, speech therapist and neuropsychologist.
Conclusions. – Numerous operating tools and technology transfers are available for neurosurgical teams performing awake brain surgery but none – or very few – of them constitutes a mandatory prerequisite. In contrast, the transition from the concept of eloquent brain area to that of brain functions that must be preserved requires highly skilled multidisciplinary human resources. This goal will be more likely achieved in centers highly specialized in functional oncological neurosurgery.

1. Introduction

1.1. Background

The neurosurgeon must ask two questions when confronted with a brain lesion situated in a potentially eloquent area. The answers to these two questions will determine the choice of operating environment, and, when necessary, the choice of intraoperative tests.

The first question is whether or not the area considered is a truly functioning area. The answer to this question is not always straightforward; it may be unanimously positive for several areas – motor primary and somatosensory cortex, visual cortex, language epicenters – as the creation of such deficits is now considered to constitute malpractice in France unless they can be considered to be an unforeseeable medical complication. In the case of sites presumed to be essential for other functions, resulting in certain forms of partial language impairment, motor or visual lesions, and therefore the answer may be highly variable. Finally, the answer is usually negative for sites involving areas presumed to be essentially involved in working memory, spatial cognition, executive functions or social cognition, for example, as will be discussed below.

The second question concerns whether or not surgery will be performed in awake conditions. The "easy" answer of awake brain surgery for an operation involving an eloquent area is not as simple as it seems, as it can be complicated by two factors: the variability of the answer to the first question from one surgeon to another, and the variable assessment of whether or not it is acceptable to sacrifice a given brain function from the patient's point of view

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(quality of life), the surgeon's point of view (clinical practice guidelines), and the society's point of view (cultural aspects, legislation and jurisprudence).

This type of surgery therefore constitutes a truly complex situation. An attempt to schematically summarize this problem is proposed in Fig. 1.

The range of responses to these two questions therefore explains the heterogeneity of management currently proposed in France for some patients. The authors of this article propose awake brain surgery whenever technically possible (i.e. in the absence of medical contraindication to awake surgery) to their patients with supratentorial parenchymal lesions involving an eloquent brain area (lesion and/or surgical approach), apart from the strict standard of care for diffuse low-grade glioma in adults [1].

1.2. Equipment and choice of tests

The re-emergence and subsequent development of awake brain surgery over the last twenty years in France has been conducted in operating rooms constructed well before this conceptual revolution. In the first part of this article, the authors describe the currently available surgical, human and technological resources (with the notable exceptions of those resources described in specific chapters of this report), and indicate those that appear to be relevant in this new context: general organization of the operating room, choice of equipment, essential personnel.

However, one of the paradoxes of brain surgery in eloquent areas is that the essential tool used for these operations is not derived from technologies. Neuropsychological tests, the central element during awake brain surgery, must be appropriately selected, and intraoperative testing must then take optimal advantage of the surgical environment, which is where neuropsychological testing articulates with technology transfer in the operating room. In the second part of this article, the authors will describe the choice of tests and their modalities of implementation.

2. Surgical resources

2.1. Operating room: objectives and organization

The neurosurgeon's need for adequate tools, especially in the operating room, requires appropriate technology transfer. These transfers, in which imaging technology now plays a central role, must address several objectives.

2.1.1. Improve patient comfort

The main complaint expressed by patients during surveys concerns the comfort of the operating position [3,4]. Two positions are commonly used for awake brain surgery: the lateral decubitus position, or supine semi-sitting position, with some degree of head rotation. However, although several studies have investigated patients' satisfaction regarding peroperative comfort during awake brain surgery, to the best of our knowledge, there is no data reported in current literature regarding a specific comparison of both, and there is no standard of care on this subject. However, patient complaints expressed during surveys do not concern the ergonomics of intraoperative testing. Pain management will not be described in detail, as it is the subject of another chapter in this report.

2.1.2. Perform the available tests under the most ergonomic conditions

The risks of false-positive or false-negative responses, among other reasons inherent to the difficulties of presentation of the various tasks (both auditory and visual), must also be limited. Some aspects will be described in the second part of this article. Acquisition and real-time processing of the data collected can also theoretically allow more precise and more objective monitoring of the patient's responses. Finally, augmented reality and immersion can improve the ergonomics of intraoperative monitoring of certain tasks.

2.1.3. Operating room organization

Awake brain surgery is based on teamwork in interaction with the patient. The authors consider that, as far as possible, the operating room must facilitate optimal sharing of information between the various personnel, by making intraoperative visual and audio information accessible under real-time conditions to all personnel, including neurologists, speech therapists and psychologists, faced with the relatively confined operating field, limiting access to the patient. Anesthetists must also have access to this information, as their access to the patient's head is limited during brain surgery in general. However, no consensus has yet been reached regarding this choice, as some teams prefer a different approach, involving examiner-blinded testing. In practice, both options may be useful at different stages of surgery.

It was in this context that the authors conceived and proposed a model operating room designed to achieve all of these objectives [5] (Fig. 2). Other similar approaches have also been reported [2,6]. These operating rooms are obviously designed to take advantage of the relevant technology transfers as they become available. As installation of these new operating rooms is dependent on equipment renewals and budget constraints, it must be stressed that these technology transfers constitute a progress and not a prerequisite, and each team can perform awake brain surgery by using the standard of care technological tools available at their institution. The genuine sophistication of awake brain surgery is cognitive and thus, must not be dependent on technological and financial imperatives. It is not at all provocative to repeat that a major virtue of awake brain surgery is that it is accessible to all countries, even the poorest countries [7].

2.2. Essential personnel

2.2.1. Neurosurgeons

In general, it has been clearly established that specialization is an essential factor in the improvement of surgical results, particularly in neuro-oncology [8,9]. Awake brain surgery is an excellent illustration of this principle, as it requires specific technical and cognitive skills by the neurosurgeon. Awake brain surgery constitutes a subspecialty and the development of neurosurgeons essentially or even exclusively specialized in functional brain surgery would appear to be desirable. Although a minimum level of activity would be difficult to propose, and even more difficult to impose, a minimal frequency of approximately one awake brain operation per week would appear to be reasonable and realistic. Tools designed to facilitate this specialization are available, allowing junior (as well as more experienced) teams to monitor their learning curve and assess their real level of expertise [10].

2.2.2. The concept of teamwork in functional neuro-oncology

This concept of specialization does not only apply to the neurosurgeon, as the training of specialized teams, in which all disciplines are represented (operating personnel, as well as neuroradiologists, neuro-oncologists), can lead to the creation of highly specialized centers [11]. Note that, in practice, it is essential for each awake brain surgery center to comprise several anesthetists, and neurosurgeons must clearly explain the justification for this choice [12].

2.2.3. Speech therapists and neuropsychologists

Speech therapists and neuropsychologists play a crucial role in awake brain surgery. At least one of these two disciplines, but