Awake craniotomies in South America: Advancements, challenges, and future prospects

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ABSTRACT

BACKGROUND: Awake craniotomy has emerged as an advanced surgical technique, characterized by keeping the patient awake during brain surgery. In South America, awake craniotomies have grained traction in neurosurgical practices across various medical centres and hospitals, with notable practitioners contributing to its growth and refinement in the region.

PURPOSE: This study aims to explore the integration and impact of awake craniotomies in South American neurosurgical practices. The focus is on understanding the benefits, challenges, and potential transformative effects of the procedure in the region.

RESEARCH DESIGN: A comprehensive narrative review and analysis through a thorough examination of the existing literature.

RESULTS: The findings indicate that awake craniotomies in South America offer substantial benefits, including cost savings thorugh reduced hospitalization time, quicker recovery and decreased morbidity. Enhanced safety, effective pain management and reduced anaesthesia also contribute to this.

CONCLUSION: Whilst the adaptation of awake craniotomies in South America holds great promise in transforming neurosurgical care in the region, significant challenges hinder its widespread adoption. Inadequate infrastructure, limited access to equipment, financial instability, and shortages in trained healthcare providers represent challenges that need to be addressed.

KEYWORDS: Awake craniotomy, South America, neurosurgery, brain tumours

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Background and current trends in awake craniotomy practice

Awake craniotomy (AC) is a surgical procedure in which the patient is kept awake during brain surgery to assess their neurological functioning and responses in real-time.[1] Of particular note, this enables the surgeon to remove a tumour or lesion from a region of the brain that controls critical functions such as speech, motor abilities, or vision, while limiting the risk of neurological impairment.[1,2]

Awake craniotomy has gained prominence as a highly regarded medical procedure in South America due to its demonstrated efficacy in treating diverse neurological conditions such as epilepsy, developmental venous anomalies, and brain tumours, including intricate supratentorial primary brain tumours.[3-5] Notably, the initial application of AC for the treatment of low-grade gliomas occurred in Peru.[6] Subsequent to this pioneering use, the adoption and administration of AC procedures have progressively diffused across a multitude of South American nations, including Argentina, Brazil, and Chile, garnering positive acclaim.[4,5,7,8]

Despite being in the early phases of implementation within the region, various medical centres, such as Grupo Gamma Rosario Private Hospital in Argentina, Antonio Pedro University Hospital in Brazil, and Carlos van Buren Hospital in Chile, have successfully formulated and executed their own AC programs.[4,7,8] In addition, noteworthy practitioners in the region, including Dr Alicia Becerra in Peru, Dr Gabriela Moguilner in Paraguay, and Dr Tatiana Vilasboas in Brazil, have used their extensive expertise in the development, wide-scale dissemination, and implementation of AC in the region.[9]

Awake craniotomy has proven to be remarkably cost-effective by reducing the duration of patient stay and hospitalisation and reducing overall morbidity and mortality.[4,5,7,10] However, despite its advantages, this procedure has not been fully explored and incorporated into practice in many countries in the region, and several barriers persist, affecting its implementation in the region. These include inadequate and below-par infrastructure, limited access to equipment and

technology, issues with the funding and pooling of resources into the healthcare system, and a shortage of trained healthcare providers.[11,12] To this end, this article aims to highlight the benefits of AC in South America, identify the challenges to its delivery, and offer recommendations and future prospects for implementing this procedure.

Methodology

This narrative review, focused on the management of AC in South America, utilised a rigorous methodology. The approach involved an extensive search of published literature, concentrating on studies conducted within the South American region. The inclusion criteria encompassed studies of diverse designs, such as observational, case-control, cohort, and randomised controlled trials, involving both paediatric and adult populations. The review specifically considered articles published in English within the timeframe of 2000 to 2023 to capture contemporary practices and technological advancements in AC in South America. The selected studies involved patients who had undergone AC.

For the literature search, databases including PubMed, EMBASE, Google Scholar, and the Cochrane Librarywere employed. The search utlised precise terms combining Precise "awake craniotomy" with geographical identifiers such as the names of South American countries, "LMICs", "low-middle income countries," and "South America". This approach ensured a targeted exploration of literature to our specific area of interest. Additionally, a manual search was conducted to identify references for recently published, procedure-specific reviews that could provide additional insights into the management of AC in South America. Abstracts standing alone and unpublished studies were excluded from the review.

Through this meticulous and comprehensive methodology, the review aims to offer a high-quality academic assessment of the contemporary management of AC in South America. The intention is to provide a detailed synthesis of relevant findings that may have broader applicability to similar income settings. The methodology employed is summarised in Table 1.

The current status of neurosurgical oncology in South America; advancements and obstacles

Neurosurgical oncology in South America has undergone substantial development and advancement in the last decade, with notable progress observed in countries including Brazil, Chile, Colombia, and Uruguay.[5,8,13-15] The adoption of sophisticated technologies, such as neuro-navigation and intraoperative magnetic resonance imaging (MRI), has become increasingly prevalent across the region.[16] This widespread integration of advanced tools has contributed to enhanced efficacy and efficiency in neurosurgical interventions.[16] Uruguay, for instance, incorporated neuronavigation for the first time in 2010, marking a significant milestone in neurosurgical practice in the region.[15]

Many South American nations, including Uruguay and Argentina, have recognised the importance of multidisciplinary care for patients with brain tumours, and have invested in and incorporated neuro-oncology multidisciplinary teams (MDTs) comprising neurosurgeons, radiation oncologists, and medical oncologists into mainstream neurosurgical practice.[15,17,18] Also, the availability and access to advanced imaging techniques such as positron emission tomography-computed tomography (PET-CT) has also widely increased, aiding in accurate diagnosis and treatment planning.[18] In addition, there has been a massive increase in the number of dedicated neuro-oncology centres, and to some degree, increased investment into neurosurgical training, and a consequent increase in the number of neurosurgical staff.[14,17] For instance, in Brazil, there has been a significant increase in the number of neurosurgery training programs, with more than 36 programs currently available across the country.[14] Similarly, these programs are being held

Table 1. Summary of methodology for management of awake craniotomy in South America.

METHODOLOGY STEPS	DESCRIPTION
Literature search	PubMed, EMBASE, Google scholar, the Cochrane library
Inclusion criteria	Full-text articles published in English in the between 2000 to 2023
	Various study designs, such as observational, case-control, cohort, cross-sectional, and randomised controlled trials.
	Studies involving paediatric and adult populations.
Exclusion criteria	Stand-alone abstracts and unpublished studies.
Search terms	Key phrase "awake craniotomy"
	Combined with geographical markers like "LMICs", "low-middle income countries", and "South America".
Additional search	A manual search was conducted to find references for recently published, procedure-specific reviews.
Sample size requirement	No strict sample size requirement.

in Venezuela, Colombia, Ecuador, and Peru, among others.[12,19]

South American countries have undoubtedly made significant strides in this regard, however, several challenges persist. In Peru, a national survey found that many hospitals faced a shortage of advanced medical imaging technology, including computed tomography (CT) scanners and MRI machines.[20] At the same time, the majority of these hospitals also lacked access to basic materials, equipment, and supplies necessary for neurosurgical care.[20] A shortage of neurosurgeons and wider neurosurgical staff still widely persists in the region. This is particularly evident in some nations more than others; compared to the recommended ratio of 1 neurosurgeon per 100,000 people, both Paraguay and Guyana had fewer neurosurgeons per 100,000 people in 2018 with .38 and .26 respectively.[21,22] Suriname, unfortunately, had zero neurosurgeons.[22]

Furthermore, the lack of reliable tumour registries in South American countries has made it impossible to accurately assess the true burden of central nervous system (CNS) tumours in the region. For instance, in Chile, there is currently no national cancer registry, which poses significant challenges in tracking disease trends and allocating resources effectively.[23] Studies have shown that Argentina, Brazil, Chile, and Uruguay have high to intermediate levels of CNS tumour incidence rates. However, these rates are deemed inaccurate due to under-reporting and under-ascertainment of cases.[24]

AC in South America: Practice, outcomes and recent advances

Considering that the vast majority of South American countries, including those with the highest populations such as Brazil and Argentina, are categorised as low and middle-income countries (LMICs) by the World Bank,[25] it is crucial for any surgical procedure to be cost-effective, has high patient satisfaction, and provide outcomes that are comparable to or better than standard procedures to be fully and widely incorporated into mainstream neurosurgical practice. Emerging evidence has suggested that ACs have demonstrated the potential to satisfy the above-mentioned criteria, creating the prospect of being a highly advantageous addition to the mainstream neurosurgical practice in the region.

Existing practice of AC in SA

Assessment of pre-surgical evaluation. Prior to AC, a thorough pre-surgical assessment is conducted to gauge the patient's neurological status and identify potential risks. In a representative case, there were no reported sensory deficits or weakness in the patient's upper and lower limb muscles.[4] A coin rotator task was employed to objectively assess hand function, revealing impairment.[4] Additionally, a brain MRI scan displayed a heterogeneous subcortical haemorrhage at the corticospinal tract level.[4] Pre-operative MRI was also performed for further diagnostic insight.[8]

Assessment of intraoperative evaluation. During AC surgery, intraoperative mapping is utilized to map both languages of bilingual patients, aiming to prevent postoperative neurologic deficits.[26] Neuromonitoring, involving techniques such as motor-evoked potentials, somatosensory-evoked potentials, and phase reversal, is employed during the surgery.[27]

Post-surgical evaluation. Following AC, various evaluations are conducted to assess the surgical outcomes. A CT scan showed complete resection of the haemorrhage.[4] An MRI 8 months post-surgery confirmed the complete resection of the lesion.[4] A motor exam 12 months post-surgery indicated improvement in hand function, assessed via the coin rotator task.[4] Other assessments include postoperative VAS mean score,[10] postoperative MRI,[28] and histopathologic examination to confirm the diagnosis.[26]

Assessment of protocols and tests. Diverse protocols and tests are employed in AC procedures. Notably, optic neuronavigation, frontoparietal craniotomy, four-channel electrode strips, dissection under microscopic magnification, neuronavigation, and high-frequency monopolar cortical mapping are utilised in certain cases.[4] Another approach involves the use of dexmedetomidine plus remifentanil for sedation, along with a solution of epinephrine, lidocaine, and bupivacaine for local anaesthesia. Rigid pin fixation and frameless stereotaxy are part of this technique.[7] AC via direct electrical stimulation (DES) is conducted, with DES being considered the gold standard.[8] Circles are drawn during the procedure to ensure no mismatches between the local anaesthetic and pin locations, utilizing tools such as ARTFIX (temporary fixation) for this purpose.[10] Language monitoring tests, alternating a name task in Portuguese and English, and a semantic task in Portuguese, are also incorporated.[26]

Standardised tools and methods. Despite the variety in protocols and tests, there is a lack of standardised tools and methods across the studies. Some variations include the use of local anaesthesia in certain cases,[4] while others employ general anaesthesia.[27] The rationale for these choices is not consistently identified, highlighting the need for standardisation in AC practices within the South American context.

AC improving patient outcomes and increased patient satisfaction

Primarily, AC has proven to be of remarkable benefit in improving patient outcomes, particularly by enhancing overall recovery and reducing post-operative morbidity and mortality. A Brazilian study involving 79 patients demonstrated that AC practices massively improved the post-surgical recovery of motor and speech deficits in patients with primary supratentorial brain tumours.[5] A long-term follow-up after a year revealed no tumour growth in 50% of the study population.[5] Positive outcomes were also observed in patients

with cavernous malformations and epidermoid cysts; AC resulted in complete recovery of affected functions.[26,28,29] In addition, AC procedures also score highly on patient satisfaction. A Brazilian study of 17 patients found that 88% held the surgery in a positive light, and preoperative apprehensions of possible paralysis and serious neurological deficits were assuaged. These patients also reported complete painlessness during the procedure, with only 2 patients complaining of slight discomfort during scalp infiltration, which was then immediately treated. The only significant cause of anxiety was psychological and associated with the sounds from the drill. All patients felt well enough to be discharged at most 3 days post-surgery.[7] Furthermore, in comparison to surgeries performed under general anaesthesia, including craniotomies, many patients undergoing AC have expressed a preference for the latter based on their previous surgical experiences.[7]

Advancements in technology and successful treatment outcomes

AC has also shown proven benefits in aiding pain management, reducing the amount of anaesthesia required during the procedure, and visualising sites of infiltration that might be hidden. A study conducted in Argentina on 13 ACs and one awake C1-C2 fusion found that the technique was particularly helpful for hairy scalps, as the infiltration sites are relatively concealed.[10] The study also found that drawing circles around the plungers allowed for the precise placement of pins and the usage of only 30% of the initial anaesthesia dosage, saving other doses for further potential pain management.[10]

Technological advancements, including intraoperative brain mapping and monitoring techniques, have markedly enhanced AC, empowering surgeons to undertake increasingly intricate procedures with heightened precision and safety. Notable, a case in Argentina exemplifies the pivotal role of contemporary awake mapping techniques in achieving surgical success. AC demonstrated efficacy in addressing subcortical haemorrhages in this specific patient, who presented with acute left-hand paresis and underwent surgical drainage through an AC.[4] The procedure successfully removed the haematoma without causing ischemia or venous infarction. Two weeks later, the patient's hand function had improved.[4]

Cost effectiveness and the wider socio-economic context

The practicality and cost-effectiveness of ACs are perhaps the predominant factors encouraging the widespread implementation and uptake of AC practices in the region. Illustratively, a noteworthy investigation conducted in Iran revealed that the cost of AC per patient within a limited-resource center is comparatively lower than that within a fully equipped facility. This observation suggests that AC procedures exhibit enhanced cost-effectiveness in resource-limited settings.[30]

The cost-effectiveness of a particular neurosurgical procedure is determined by a plethora of factors. One of the most important considerations when determining the total cost of a neurosurgical procedure is the postoperative hospital stay.[27] Empirical evidence emerging from AC procedures in the region has repeatedly demonstrated how the uptake of such procedures has dramatically reduced the postoperative stay of patients, leading to a dramatic decrease in the long-term costs associated with the care of patients undergoing AC procedures.[7,26] As previously elucidated, emerging evidence from AC practices in the region has shown how the utilisation and hence the overall requirement of intraoperative medication, especially anaesthesia, are lower in AC procedures.[10] Studies have demonstrated how increased levels of anaesthetic used within a patient are directly correlated with longer hospital stays and increased rates of overall postoperative mortality.[31,32] Therefore, by requiring fewer amounts of anaesthesia, AC practices not only directly reduce costs by saving on drug spending but also indirectly reduce costs by reducing hospital stays.

The aspect of cost-effectiveness has to also be assessed from a wider socioeconomic perspective. Numerous studies conducted in the region have demonstrated how AC practices lead to reduced levels of post-operative morbidity and mortality.[10,26,28,29] Traditionally, greater rates of postoperative complications following conventional and antiquated neurosurgical procedures have led to the premature withdrawal of patients from the labour market, which has significant impacts on the overall economic well-being of the country.[27,31,32] Thus, by reducing the overall levels of postoperative complications, AC ensures that patients can return to their normal lives and livelihoods much quicker than usual and can contribute to the economic prosperity of the country.

Challenges associated with the wide-scale implementation of AC in South America

Shortage of neurodiagnostic and neurosurgical equipment

A fundamental impediment hindering the establishment of AC practices in South America is the scarcity of resources, particularly a shortage of the technical equipment necessary for the meticulous execution of procedures.[11,30] Compared to higher income countries (HICs), the availability of functional magnetic resonance imaging (fMRI), diffusion tensor imaging, MRIs, neuronavigation devices, and both motor evoked and somatosensory evoked potentials is very scarce or limited in South America.[11,33] The shortage of such essential equipment greatly hinders the ability of the neurophysician to ensure a viable mapping of the brain prior to the procedure.[30] In addition, the significant cost of over 50,000 USD for equipment combined with an inconsistent supply of power further hinders the accessibility of cortical mapping.[34] Neurosurgeons in the region hence rely chiefly on a meticulously conducted neurocognitive assessment for brain mapping, relying predominantly on the

age-old notion of concept and principle over technology.[11,33] Brain mapping technology, including fMRIs, magneto-encephalographic, and intraoperative cortical stimulation devices, has the primary benefit of providing a comprehensive real-time image of the brain during ACs, providing neurosurgeons with enhanced perception and a better understanding of what cortical areas (including those involved in language processing, sensory perception, and motor functioning) to preserve.[35] The widespread utilisation of such brain mapping technology allows surgeons to critically appraise and tailor the craniotomy procedures based on the critical functional brain regions; in contrast, relying on neurocognitive assessment, as is the general consensus in South America, does not provide the same level of precision, which translates into poorer outcomes for South American patients.[11]

The issue of staffing, workforce, and training

Another predominant constraint impeding the widespread development of ACs in the region is the shortage of a trained multidisciplinary staff.[22,30] It is a general consensus that procedures such as ACs require the presence of a well-trained neurosurgeon and an anaesthesiologist.[31]The World Health Organization´s (WHO) Human Resources for Health criteria specify that for the safe provision of healthcare, there has to be a minimum ratio of 25 health professionals per 10,000 people.[36] However, a deeper insight into South American health workforce statistics reveals poor results.[22] Peru, for instance, has failed to reach this target to date. In Colombia, over 40% of the doctors practice in the primary setting, with a severe lack of tertiary care doctors, including those in the field of neurosurgery and anaesthesia.[36,37] Although Colombia and Peru have been able to achieve a 1:1 physician-to-nurse ratio, other nations on the continent have massively struggled to achieve this.[36] In addition, the issue of a shortage of workforce is compounded by inequalities and inequities in distribution. For instance, in Peru, over 50% of the health workforce is based in the capital city of Lima, severely exacerbating staff shortages in rural regions of the country.[38] Such studies shed light on the massive dearth of neurosurgical and anaesthetic staff on the continent.

Furthermore, the shortage of staff is compounded by a lack of specialised skills required to conduct craniotomies in an awake setting.[11,22,38] A Brazilian study conducted by Albuquerque et al qualitatively narrates how the issue of staffing and workforce translates into practice. Initially, the study elucidates the difficulty in convincing not only neurosurgeons and anaesthetists but also allied health professionals such as neuropsychologists and speech therapists to partake in such procedures.[11] The study further details the necessity for numerous 'training meetings' to align perspectives, address misconceptions, and improve neurosurgical technique, even before entering the operating theatre. Additionally, it highlights the critical need to enhance the learning curve of the staff and underscores how the insufficient exposure contributed to avoidable errors, particularly in patient positioning and airway management in the lateral position.[11] This empirical evidence underscores the severity of the situation, especially within the South and Latin American contexts.

The lack of institutional adaptation

Moreover, a significant concern in the South American context is the limited adoption and adaptation of AC procedures into contemporary medical practice.[11] In Brazil, for example, there is currently no provision for formal AC-focused training for staff, and there is a lack of formally established institutional frameworks, whether at the national or loca level, to fully integrate ACs into routine practice.[11] Albuquerque et al dehighlight that the concept of AC and the overall approach are rooted in a French model, which may not align well with the South American population.[11] While the number of studies detailing various South American nations' experiences with AC procedures has increased in recent years,[5,7,8,10] there remains a scarcity of studies analysing how these initial experiences can be adapted into the broader South American context, as well as normative data from tests specific to the South American cohort.

Additionally, the broader context of incorporating AC practices into the medical system, including determining the requisite number and roles of staff for the procedure and establishing billing procedures for patients, is not well-established.[11] Specialised procedures like ACs necessitate close collaboration and communication with neuroscientists and psychologists, requiring cognitive tests to assess patient functioning before the craniotomy procedure.[39] Compared to HICs, there is a general deficiency of office space, staff, and funding needed to conduct such specialised neurocognitive tests, further hindering the successful implementation of AC programs into mainstream South American practice.[11]

Challenges with education and training

Adding to our extensive list of challenges is the issue of procedure education and training and the further dissemination of information. In South America, only 75% of nations have neurosurgical training programs, highlighting the grave shortage of available methods to teach and disseminate AC education.[12] In addition, another area of grave concern is the dissemination of information, particularly to the future generation of neurosurgical staff. An empirical analysis of the current literature available on Pubmed, suggests that some hospitals in Argentina have been able to perform AC procedures successfully due to the specialized expertise and experience of certain individuals.[8] However, this is not the case for hospitals throughout the country as these skills seem to be limited to specific institutions and have not been widely disseminated. Therefore, such a situation has led to the development of

neurosurgical inequities: there are a handful of hospitals with specialized AC programs, while within the same region, a vast majority of hospitals lack the skills required to successfully implement their own AC programs. Such an issue concerning the inadequate spreading of information, even that pertaining to AC education, is unfortunately quite common not only in South America but also in the wider LMIC context.[40]

Socio-economic constraints

The broader challenge in achievingsuccessful implementation of AC practices in South America is rooted in the overarching socioeconomic context. While institutions have made strides in implementing AC practices and procedures in recent years, a notable deficiency persists in postoperative support.[41] AC surgeries need to be supported with post-operative rehabilitation programs. However, a shortage of investment in public healthcare means that the facilitation of such programs is often not possible.[41] In countries like Peru, over one-fifth of the population is excluded from the healthcare system. Consequently, patients frequently encounter challenges in covering treatment expenses independently, necessitating governmental support.[42] Another major hindrance to the delivery of ACs in the region is the difficulty of patient follow-up owing to economic constraints; difficulties in accessing care, issues with transportation and hospital visits, and barriers to physician-patient care often mean the follow-up of patients is extremely challenging.[11] Finally, the lower levels of health education and literacy act as cultural impediments to the uptake of such procedures.[11]

Huge AC research gaps in South America

AC research is critical for improving patient outcomes by increasing doctors' awareness of the technique and establishing the optimal methods for monitoring cognitive function during surgery.[43,44] HICs have done much study on AC, which has improved physicians' understanding and use of this technique.[43] Despite its importance, most South American countries have considerable research gaps regarding the use of AC. Guyana, Ecuador, and Suriname, for example, have no reports on the outcomes of ACs in their countries. The absence of research in this area is quite concerning since it shows that little is known about the usefulness and safety of AC in these areas. Furthermore, even the AC studies originating from the region have been based predominantly in Brazil and Argentina only.

The lack of AC research in South America may have a number of detrimental implications. Without adequate research, medical personnel may lack access to the most recent breakthroughs and best practices for executing the surgery, thus jeopardizing patient results. The scarcity of studies may also impede politicians' and healthcare administrators' ability to make educated decisions about the use of AC in South American countries, resulting in differences in the quality of care provided to patients.

Discussion and future prospects

Addressing disparities and public policy in neurosurgical care

At the grassroots level, the primary steps to deal with the inequalities and disparities in the delivery of ACs in South America should ideally stem from the development and enforcement of sound health policies at the governmental and local levels. The development of a strong political resolve to tackle disparities in neurosurgical oncology in the region should be practical; it should not only incorporate promises and visions but also a comprehensive strategy. Firstly, there has to be standardisation of AC procedures among the different South American nations. Essentially, there is a dire need to develop national guidelines; at present, the disseminated and unstandardised AC procedures, as conducted presently in Brazil, are based on French models. Such devised guidelines must take into account normative data generated within the South American context; they have to leverage existing infrastructure and resources on the continent to optimise surgical outcomes and cost-effectiveness. For this to happen, there has to be a dedicated and sustained effort to conduct a plethora of observational studies; the patients within such studies should be representative of the diverse population of the South American nations.

In addition, any central health strategies devised to tackle neurosurgical disparities also have to be sustainable; they have to explore and devise comprehensive and continued sources of funding. As discussed previously, the dearth of complex neurosurgical equipment hinders the ability to successfully implement widespread AC programs in the region. In the resource-limited South American context, increasing funding for neurosurgical delivery requires activism, extensive campaigning, and public health advocacy. In addition, alternative sources of funding should also be explored, including the development of public and private partnerships, reaching out to charitable and philanthropic organisations, and appeals to governmental bodies, including the WHO and The United Nations Children's Fund (UNICEF). Such mechanisms of increased funding will not only ensure an adequate supply of expensive neurosurgical equipment but will also generate much-needed funds to overhaul and improve existing healthcare systems.

Improving neurosurgical procedures and training for ACs

A previously discussed challenge was the lack of incorporation of AC procedures into mainstream neurosurgical practice. Hence, in South American nations, there is a strong need to recognize ACs as part and parcel of routine neurosurgical practice rather than a service only provided during times of need. In addition, there is a need to appreciate the roles of the wider neurosurgical MDT, including neuropsychologists, neuroscientists, and dedicated

neurosurgical nurses. It is essential to integrate these crucial professionals into mainstream AC programs.

It is self-evident that improving the delivery of AC programs within the region requires an investment in neurosurgical staffing and workforce. Such an investment should ensure not only the increased training of neurosurgical staff (surgeons, nurses, and allied neurosurgical healthcare workers) but also the incorporation of dedicated AC teaching programs, such as fellowships, into mainstream neurosurgical curricula. In addition, there is a potential to foster collaborations between highly specialised institutions; for instance, the Duke Neurosurgery program provides a fantastic opportunity for neurosurgical staff in LMICs to train and hone their skills in the United States and export these skills back home. There is also a need to create an environment of information sharing, the spread of skills amongst staff, and an atmosphere of learning, sharing, and dissemination of information.

Improving technological advancements and innovation for ACs

In such resource-constrained settings, South American nations can benefit from innovations in technology to widen access to care. For instance, new advancements in fMRI can improve the pre-surgical evaluation and localization of tumours. Thus, less invasive and precise techniques can be applied when performing ACs, leading to better results and decreasing costs. Additionally, artificial intelligence is an emerging technology in healthcare that can also benefit ACs conducted in LMICs. For example, some authors have described using deep neural networks in order to improve the quality of CTs; therefore, these can be the primary imaging technique for pre-surgical planning, avoiding using more expensive imaging techniques.[45]

In this modern era of technological advancements, artificial intelligence can be of great benefit in making the delivery of care more efficient. For instance, chatbots and web

Table 2. Summary of discussions and prospects.

FUTURE PROSPECTS	DESCRIPTION
Addressing disparities in public policy	
Standardising AC procedures	• Development of national guidelines for AC procedures to ensure standardisation.
	• Utilisation of normative data specific to the south American context.
Sustainability health strategies	• Conducting observational studies representative of the diverse population in the region. • Development of comprehensive and sustained funding sources for neurosurgical care.
	• Activism, public health advocacy, and partnerships with public/private entities.
Improving neurosurgical procedures and training	
Incorporation of AC into routine practice	• Recognition of ACs as routine neurosurgical practice.
	• Integration of neuropsychologists, neuroscientists, and neurosurgical nurses into AC programs.
	• Investment in neurosurgical staff training and dedicated AC teaching programs.
International collaboration	• Promotion of collaborations with specialised institutions, facilitating knowledge transfer.
	• Creation of an environment for information sharing, skill development, and collaborative learning.
Improving technological advancements and innovation	
Leverage technological innovations[45]	• Adoption of fMRI for enhanced pre-surgical evaluations and tumour localisation.
	• Integration of artificial intelligence for cost-effective and efficient imaging techniques.
	• Utilisation of deep neural networks to improve CT quality for pre-surgical planning.
Telemedicine and accessibility	• Exploration of telemedicine options for increased accessibility in rural settings.
	• Development of chatbots and web applications for faster identification of patients.
	• Utilisation of telemedicine for post-surgical follow-up of ACs.
Tackling fear and anxiety	
Enhancing perception of healthcare[46]	• Allocation of resources to improve the overall perception of healthcare in the region.
	• Active initiatives to address fear and anxiety linked with neurosurgical interventions.
	• Involvement of clinical neuropsychologists in pre-operative, intra-operative, and post-operative phases.
Standardised psychological protocols[46]	• Establishment of standardised protocols for clinical psychologists.
	• Outline of assessment toolkit, interview schedule, and pre-post neuropsychological assessments.

AC, Awake craniotomy; fMRI, functional magnetic resonance imaging.

applications that can allow the user to identify the need for neurosurgical care faster can decrease the burden of many diseases by reducing the time gap from primary care consultation to referral for specialised care. Faster identification of patients can lead to better pre-surgical evaluations, improving the effectiveness and safety of ACs in LMIC. In addition, telemedicine options can increase accessibility to neurosurgical care in rural settings, allowing more patients to be informed and receive ACs. Moreover, telemedicine presents a valuable utility for post-surgical follow-up of ACs.

Tackling fear and anxiety associated with AC

In the broader geopolitical context, there is a pressing necessity to allocate resources to enhance the perception of healthcare within the region. Active and sustained initiatives are required to address the fear and anxiety associated with neurosurgical interventions, specifically AC.[46] In this context, the involvement of clinical neuropsychologists is paramount throughout the entire AC process, encompassing the pre-operative, intra-operative, and post-operative phases, particularly in relation to the psychological well-being of the patient. Establishing a standardised protocol is imperative for clinical psychologists, outlining the assessment toolkit, interview schedule, pre-surgery intervention techniques, and pre-post neuropsychological assessments.[46] The discussions and prospects have been summarised in Table 2.

Conclusion

AC has emerged as a safe and effective surgical technique in South America for treating brain tumours, epilepsy, and developmental venous anomalies, among other conditions. AC has proven beneficial in improving patient outcomes, reducing hospitalisation time, and increasing patient satisfaction. The use of AC has also led to advancements in technology, enabling surgeons to perform even more complex procedures with greater precision and safety. However, the implementation of AC in South America has been limited by challenges such as a shortage of neurodiagnostic and neurosurgical equipment, limited access to technology, a financially unstable healthcare system, and a shortage of trained healthcare providers. Addressing these challenges requires investment in equipment and infrastructure, as well as increasing access to training and education. Despite these challenges, the benefits of AC make it a worthwhile pursuit in South America and beyond.

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