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SURGICAL SITE INFECTIONS IN OPEN CRANIOTOMY – A NARRATIVE LITERATURE REVIEW

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Summary

Open craniotomies are modern surgical interventions that, despite their high complication rates, including postoperative infections, remain a reliable choice due to their favorable surgical outcomes. They are often used in conjunction with other methods to enhance treatment efficacy. A critical review of 191 sources was conducted, identifying 64 relevant studies published between 2014 and 2024 that met stringent inclusion/exclusion criteria. Afterwards 3 additional selective studies were included in the review. Elective methods, in conjunction with open craniotomies, have been found to be reliable treatment options for neurosurgical conditions. The risk of surgical site infections (SSIs) is primarily influenced by factors such as anatomical anomalies and the presence of highly resistant bacterial species. Advances in antibiotic engineering are aimed at providing effective treatment options for these infections. SSIs are critical considerations in every open craniotomy, irrespective of the additional treatment methods employed.

Keywords: *Surgical site infections, open craniotomy, neurosurgical complications*

Rezumat

Infecțiile de situs chirurgical în craniotomiile deschise – un reviu narativ al literaturii

Craniotomiile deschise sunt intervenții chirurgicale moderne care, desi prezintă rate înalte de complicații, inclusiv infecții postoperatorii, rămân a fi opțiuni optime datorită rezultatelor chirurgicale favorabile. Aceste proceduri sunt frecvent utilizate în combinație cu alte metode pentru a amplifica eficacitatea terapeutică. O revizie critică a 191 de surse a fost efectuată, identificând 64 de studii publicate între 2014 și 2024 care îndeplineau criteriile stricte de includere/excludere. Ulterior, au fost incluse în studiu 3 surse suplimentare. Metodele elective, alături de craniotomia deschisă, au fost recunoscute ca opțiuni de tratament de încredere pentru afecțiunile neurochirurgicale. Riscul de infecții de situs chirurgical (ISC) este influențat în mod principal de factori precum anomalii anatomice și prezența speciilor de bacterii rezistente la tratament. Progresele științifice în domeniul ingineriei antibioticelor au scopul de a oferi opțiuni de tratament eficiente pentru aceste infecții. ISC reprezintă o considerație critică pentru toate craniotomiile deschise, indiferent de metoda de tratament adițional utilizată.

Cuvinte-cheie: *infecții de situs chirurgical, craniotomie deschisă, complicații neurochirurgicale*

Резюме

Инфекций области хирургического вмешательства в открытые краниотомий – нарративный литературный обзор.

Открытые краниотомий подразумевают собой современные хирургические вмешательства которые, несмотря на высокую частотность усложнений, включая послеоперационные инфекций, остаються оптимальным выбором благодоря хорошему хирургическому исходу. Часто их применяют совместно с другимими способами чтобы улучшить терапевтическую эффективность. Критическая ревизия 191 источников была совершена, выделяя из них 64 источников которые опубликовались в течение годов 2014 по 2024 и строго соблюдали критерий включения/исключения. Позже мы добавили еще 3 независимые источники в добавок к прежним. Выборочные методы, в совместности с открытой краниотомией, были доказаны быть надёжными способами терапевтического вмешательства для нейрохирургических обстоятельств. Риск для инфекций области хирургического вмешательства (ИОХВ) первородно зависит от таких факторов как анатомические аномалий и присуствие бактерий с высокой резистентности к антибактериальным средствам. Научный прогресс в инжинерий антибиотиков направлен на предоставление эффективных способов в лечение данных патологических состояний. ИОХВ состовляют собой критические расмотрения для всех открытых краниотомий, невзирая на дополнительный способ лечения который замешан.

Ключевые слова: *инфекций области хирургического вмешательства, открытая краниотомия, нейрохирургические осложнения*

Introduction

Open craniotomies are performed in the neurosurgical field despite the availability of alternative techniques in this anatomical region [1-3]. Surgical site infections (SSIs) are prevalent nosocomial entities across various medical specialties, but higher regard is given to the above-mentioned approach, particularly due to their long-term sustainability [2, 4]. Despite the growing threat of antibiotic resistance, experts are exploring alternative methods to prevent SSIs [5-8].

These infections can significantly extend hospital stays, as patients may remain in critical condition for longer periods [4]. Notably, no perioperative infections have been reported in the surgical implantation of neurostimulator devices for Parkinson's Disease, as the electrodes possess antiseptic and aseptic properties. These infections are primarily associated with open craniotomies [9-10].

Brain abscesses may sometimes progress into glioblastomas according to recent scientific reports [11], with a lack of clear evidence for this statement. Imaging methods do not directly influence the clinical outcomes in the means of nosocomial infections, as they are not directly involved at the infection site, whereas craniotomies pose a significant threat to patient survival during the clinical stage [4, 12-14].

The **aim of the study** was to emphasize the importance of surgical site infections in open craniotomies to obtain better outcomes in the operating theater and surgical ward.

Materials and methods

On 13.04.2024, a search of the PubMed database using the keywords 'infection' and 'open craniotomy' yielded 191 sources. From these, 64 relevant studies were considered based on stringent inclusion/exclusion criteria. Afterward, three additional selective sources were included in the review.

Included articles were published between 2014 and 2024, demonstrated statistical relevance concerning surgical site infections in craniotomies, and had no conflicts of interest. Excluded sources involved animal studies, different surgical interventions, protocol validations, and odontogenic infections.

Results

A series of influencing factors were regarded for the SSI and those are – male gender, previous surgery, subgaleal drainage of pathologic collections, foreign materials, and ventricular openings. These factors are not direct risk factors but indirectly contribute to the surgical outcome [15].

To avoid open craniotomies, laser interstitial thermal therapy (LITT) can be performed, sometimes in conjunction with other specific therapies. In some cases, LITT may be followed by a craniotomy to mitigate the sequelae of surgical interventions, such as glioma resection, providing a comprehensive approach to tumor removal [16].

It must be noted that repeated surgical interventions are not proven to provide significant improvement, particularly due to predefined outcomes related to the severity of the condition when extensive neurovascular tissue in the central nervous system (CNS) is affected [17].

Radiosurgical interventions can be augmented by LITT to avoid its complications, although inevitable sequelae often accompany radiotherapy [18]. Repeated trepanations can lead to infections without the resolution of the primary pathologic condition, rendering them generally a one-time attempt for this purpose [19]. Bedside percutaneous three-millimeter twist-drill trephination is a safer and more effective alternative to classical methods, offering advantages such as lower costs, fewer specialists required, and faster execution [20]. Brain biopsies are not proven to cause nosocomial infections, as these infections are primarily due to direct involvement during surgical interventions [21]. The transpalpebral approach has fewer postoperative infections due to its conservative surgical field expansion and reliable closure technique [22].

The microscopic method does not have a higher infectivity rate than the endoscopic one in neurosurgery, while it is proven that neuroendoscopy is relatively inoffensive in cranioplasty performed in children (0.4% infection rate compared to 6.2% in open craniotomy) demonstrating significant advantages in neurosurgery [3, 23]. Additionally, posttransfusion infections are uncommon across all population groups [3]. Frontal sinus reconstructions can decrease the incidence of postcraniotomy infections [24].

Several comorbidities, such as pneumonia, sinusitis, and otitis media could exacerbate after surgical interventions, leading to secondary infections due to hematogenous, direct contact, and otogenic routes of cerebrospinal fluid (CSF) transmission [25-27].

CSF leakage from the dura mater is associated with higher infection rates, independent of the closure technique, and primarily influenced by the initial stages of the surgical intervention [14].

Specific complications and/or exacerbations characteristic of this region in the case of surgical involvement include brain abscesses, neurocysticercosis, cerebral toxoplasmosis, mycotic aneurysms, nasal dermoids, encephalitis, Pot Puffy's tumor, multiloculated hydrocephalus, and arachnoid cysts [26, 28-34].

The preauricular sinus is an anatomical anomaly that can become infected and mimic the clinical signs of a SSI or systemic infection [36]. Seizures can be induced by both antibiotic overdose and cerebral abscesses, primarily due to drug reactivity and the biochemical compounds delivered into the bloodstream via leukocytes [36-37].

Surgical site infections (SSIs) in open craniotomies involve complex biochemical interactions between pathogens and host tissues. The primary biochemical processes implicated include the disruption of the blood-brain barrier, immune response modulation, and pathogen virulence mechanisms. Key biochemical markers such as pro-inflammatory cytokines (IL-6, TNF-α) and acute-phase proteins, as C-reactive protein are often elevated in SSIs, reflecting the host's inflammatory response [38].

Additionally, bacterial enzymes like proteases and hemolysins contribute to tissue invasion and damage [39]. Comprehending these biochemical pathways is crucial for developing targeted therapeutic strategies and effective prophylactic measures against SSIs in neurosurgical procedures and not only [40-41].

Staphylococcous aureus, and *Escherichia coli* are the predominant bacteria found in cerebral abscesses [35]. Posttraumatic injury sites infected most frequently with *Staphylococcous aureus*, and *Klebsiella pneumoniae* [42]. Aspergilloma, zygomycosis, chromomycosis, cryptococcoma, mucormycosis, and Candida infections were the most prevalent intracranial fungal infections [43]. *Acinetobacter baumanii* is a well-known, highly resistant bacterium that may cause severe intracranial infections [7]. The less known *Lactococcus lactis cremoris* is not aggressive but neglected often by clinicians in the context of SSI [8].

The nasal microbiome is an independent factor for infection in patients undergoing elective surgery because it yields a high infectivity potential if it contains opportunistic species [44].

Some studies showed that gelatin sponges, drainage systems in the ventricular system with continuous irrigation, and pericranial flaps reduce the incidence of SSI [45-46]. However, it is to be noted that extraventricular drainage increases the likelihood of postoperative infection, making their location a critical factor for infectivity [47].

In terms of antibiotic treatment, Vancomycin is a trending antibiotic for treating pediatric and adult SSIs after an open craniotomy [5, 48]. Tigecycline delivered via nanoparticles through the blood brain barrier (BBB) is the elective antibiotic in infections with *A. baumanii* [7]. Overall, a better outcome is achieved if patients are discharged on the same day as their surgery; as the incidence of nosocomial infections is lower in these scenarios [2].

Discussions

LITT is a reliable method in order to improve outcomes both preoperatorely and after radiosurgery, mainly reducing the sequelae like cerebral oedema [16,18]. It is to be regarded that it is not available in many countries for each patient.

Trepanations should be considered carefuly due to their unreliability in a contemporary context [19-20] while cerebral biopsy and transpalpebral approaches are more promising [21-22], especially when cosmetic approaches are considered [24] and adequate consumables are used [45-46]. It should be noted that their effectivity is to be contested in extraordinary cases.

Numerous conditions should be considered while an SSI is to be postulated, if they are comorbidities or pathological formations is the second thought when assessing the risks [25-34]. Not the last pathophysiological aspects can become a confounding factor either in an anatomic context [36] or biochemical [36-41]. A second thought should be given when diagnosing a SSI.

The bacterial species is highly associated with the mechanism of transmission and treatment strategy and should be carefully regarded because of their emerging resistance to antimicrobial agents [5, 7, 35, 42-43, 48]. The therapeutic option is sometimes to be debated, as it may worsen the patient's state.

Lastly but not least, administrative aspects are of utter importance in the predeterminism of a surgical site infections [2], as each country and/or medical system has its particularities that balance between different benefits and downsides.

Conclusions

Surgical site infections (SSIs) following open craniotomies remain a significant concern, influenced by various factors including patient demographics, surgical techniques, and pathogen resistance. It is a limiting factor for the development of better postoperative outcomes like recurrence, and the quality of life. Antibiotic resistance poses a significant threat to current treatment strategies for SSIs and must be carefully considered. While the use of adjuvant consumables can be beneficial in surgical interventions, it is important to recognize that they are not always the optimal choice. Overall, understanding the multifaceted factors influencing SSIs and integrating advanced surgical techniques and targeted antibiotic therapies are crucial for improving patient outcomes in neurosurgical interventions.

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Conflict of interests

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