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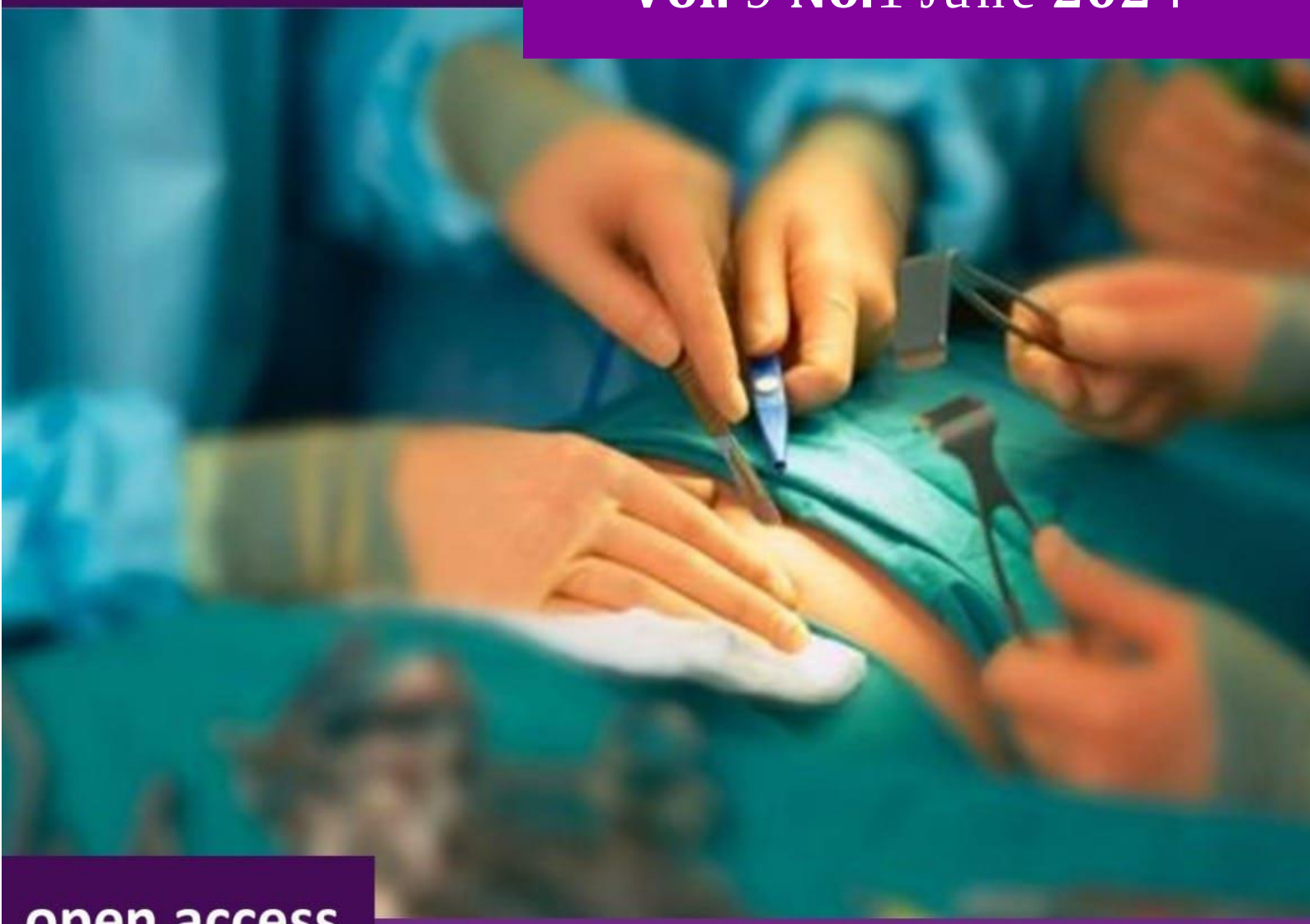

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FOCUS AND SCOPE

burn and wound, hand, microsurgery, oncoplastic, craniofacial, external genitalia reconstruction, and aesthetics.

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JURNAL
REKONSTRUKSI DAN ESTETIK

PEDIATRIC OCULAR TRAUMA MANAGEMENT: A CASE STUDY OF EFFECTIVE INTRA-ORBITAL FOREIGN BODY IOFB EXTRACTION

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ABSTRACT

Introduction: Penetrating Intraorbital Foreign Body (IOFB) injuries are a rare form of traumatic injury. Recognized as a surgical emergency, meticulous history-taking and a thorough examination are essential for determining the trauma's mechanism and cause, facilitating accurate diagnosis and effective disease management.
Case Illustration: In the emergency room, a 5-year-old female patient was presented with a craniofacial injury resulting from an IOFB. An evacuation procedure, conducted through a subsidiary incision, was performed to extract the foreign body. Interestingly, the object removed from the orbital cavity was a plastic foreign body, initially suspected to be a fractured orbital bone.
Discussion: The clinical presentation, management, and outcomes of orbital foreign body injuries can differ based on the material composition of the foreign body. In cases of intraorbital foreign body trauma, the primary treatment goal is foreign body removal.
Conclusion: Precise and accurate initial management in the emergency department is crucial. Early diagnosis, aided by a 3D head CT scan, is instrumental in locating the IOFB and identifying the involved anatomical structures. This, in turn, enables timely treatment decisions to minimize the risk of complications.

Highlights:
1. The rare nature of Orbitocranial Injury with Intraorbital Foreign Body (IOFB).
2. Utilizing a 3D Head CT Scan to ascertain the precise location of the IOFB and its impact on anatomical structures is pivotal in shaping immediate treatment strategies, thereby reducing the potential for complications.

INTRODUCTION

Approximately 14% of children's injuries are ocular, with foreign body-related injuries being a significant contributor to health issues and blindness.[1–3] Penetrating Intraorbital Foreign Body (IOFB) injuries in children under the age of five are infrequently encountered and constitute an uncommon form of penetrating trauma. Although relatively rare, this type of injury occurs across various geographic regions and constitutes approximately one-sixth of all orbital injuries. These incidents primarily affect young individuals and are typically associated with activities such as

recreational play or the application of significant craniofacial force, often resulting from accidents or routine domestic tasks.[4–6]

Diagnosing intraorbital foreign bodies can be challenging, especially with smaller objects that may not be easily visible in imaging. Failure to promptly remove these foreign bodies poses a significant risk of infection. Intraorbital foreign bodies can be categorized into metallic types, which can be further classified as magnetic or non-magnetic, and non-metallic objects, such as plant material, plastics, glass, and other materials.[6,7] The symptoms associated with this disorder are varied and depend on the extent of the injury, the composition of the foreign body, its trajectory, the speed of the impact against the orbit, among other factors. The first step to take is the stabilization of the patient to be able to perform a complete ophthalmological examination. It is important to note that not all periorbital foreign bodies need removal; the decision depends on the material and location characteristics.[5]

Computed tomography (CT) scans of the orbit and skull are important tools for identifying injury severity and making therapeutic decisions.[5,7] Even minute foreign bodies, measuring as little as 2 mm, can be readily identified in CT scans due to their typically high density. These foreign bodies typically enter the orbit and traverse the space between the orbital wall and the eyeball, often without impacting the eye itself. Rarely do they traverse the orbit to penetrate paranasal sinuses or intracranial spaces, which may potentially involve neurovascular components.[5]

Considering that craniofacial trauma, especially cases involving Intraorbital Foreign Bodies (IOFB), are considered surgical emergencies, the urgent need for swift diagnosis and management cannot be overstated.[4] An effective method is needed to conduct comprehensive clinical evaluation and perioperative management in accordance with standard protocols for handling injuries with Intraorbital Foreign Body (IOFB) in the eye in pediatric patients. In this report, we present a unique case of orbitocranial trauma in a pediatric patient. This case involves a substantial IOFB that traversed the orbit, penetrated the skull, and reached the temporal lobe without causing any harm to the eyeball.

CASE ILLUSTRATION

A 5-year-old female patient was brought to the Emergency Room after sustaining a craniofacial injury caused by an Intraorbital Foreign Body (IOFB) lodged in her right eye. This incident occurred when her father abruptly braked the motorbike during a vehicular accident, resulting in to the penetration of the motorbike's rear-view mirror shaft into her right orbital cavity.

During the initial physical examination, the conscious patient displayed stable vital signs and exhibited a foreign body (a portion of the motorbike's rearview mirror shaft) lodged in the orbit of her left eye. She had an eyelid hematoma that hindered her ability to open the affected eye, but did not reveal any obvious eye involvement or bleeding. A portion of the shaft was partially visible within the eyeball, with approximately 10 cm protruding externally. After a comprehensive examination, no additional injuries were found. Subsequently, a 3D CT scan was performed for further evaluation.

A head scan was conducted to precisely locate the foreign bodies and assess the affected bone structures. The tomographic examination revealed that the foreign body had penetrated the right side of the intraorbital region and extended toward the temporal lobe above the left eyeball. Importantly, there were no indications of intraconal or intraocular lesions, and no signs of intracranial, subdural, or epidural hematomas, or retroconal bleeding were identified (Figure 1).

After obtaining the patient's informed consent for the foreign object removal procedure, she was transferred to the operating room. Subsequently, a procedure was performed to evacuate and extract the foreign body through a secondary incision. Interestingly, the object retrieved from the orbital cavity was identified as a plastic fragment, specifically from the motorbike's rearview mirror shaft. Initially, there had been suspicion of a fractured orbital bone.

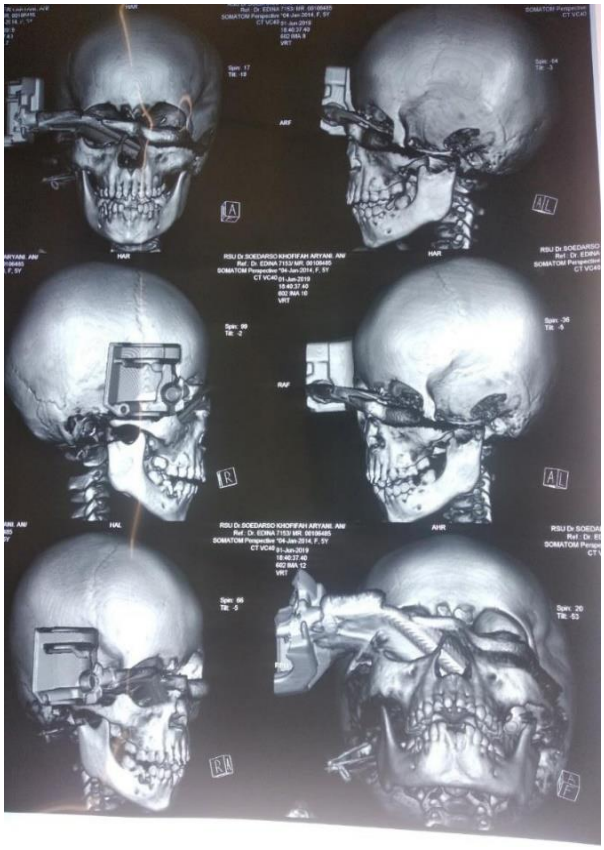

Figure 1. 3D Head CT Scan

Figure 2. Pre Operation

Figure 3. Post Operation

Figure 4. One Week Follow-up

The authors confirm that they have acquired requisite consent forms from all relevant patients, who have granted approval to report their images and clinical details in the journal. Patients acknowledge that their names will be withheld from publication, and diligent measures will be taken to obscure their identities. However, complete anonymity cannot be assured.

DISCUSSION

Injuries involving foreign bodies in the eyes of pediatric patients constitute approximately one-third of open globe injuries and introduce unique complexities in management and eye-related issues distinct from those in adults. This age group often experiences eye injuries due to active play activities and a lack of awareness of potential risks. The presence of an intraorbital foreign body (IOFB) in pediatric eyes introduces unique management complexities due to the anatomical and physiological differences compared to adults.[1]

IOFBs can cause significant damage to the eye's structures and orbital contents in pediatric patients, as these organs are still in a growing and developing stage.[10] An Intraorbital Foreign Body (IOFB) is characterized as an object situated within the bony confines of the orbital walls, positioned posterior to the orbital septum, but external to the ocular globe. It can be situated either extraconally or intraconally. IOFBs may damage eye tissues, including the lens, retina, and optic nerve, potentially impacting vision and visual development in children. Managing eye injuries in children requires careful and coordinated approaches among ophthalmologists, surgeons, and other healthcare teams to ensure appropriate treatment and minimize long-term complications. Therefore, a deep understanding of the differences between pediatric and adult eye injuries, especially concerning IOFBs, is crucial for providing optimal care to pediatric patients with foreign body-related eye injuries. [6,8,9]

Ocular injuries account for about 8% to 14% of all injuries in children.[2] This type of open orbital trauma constitutes approximately one-sixth of all cases.[9] According to a study conducted by Singh et al[11]., the occurrence of penetrating and perforating ocular injuries in children is 67.7% and 10.9%, respectively. Intraorbital foreign bodies were found in 5% of cases.[12] These traumas can result in varying degrees of damage and may affect the patient's vision.[5] Trauma is a significant contributor to health problems and is a non-congenital cause of one-sided blindness in children.13 While intraorbital foreign body-related ocular trauma is infrequent in the pediatric population, it is considered a medical emergency when it does occur.[5,13]

The three most common causes of ocular injuries are unintentional accidents, deliberate attacks, and self-inflicted harm.[14] Pediatric orbital traumas typically arise from contusive or penetrating incidents, often occurring during recreational activities (59%) and accidental tumbles or falls (37%).[5,14] The most common cause of penetrating injuries in children involved sharp objects being either poked into the child's eye by the child themselves or thrown

at the child.[12] In children aged 3 years and younger, unintentional injuries often occur at the hands of caregivers, parents, or siblings.[15] Self-inflicted injuries are also prevalent in this age group due to underdeveloped hand-eye coordination and fine motor skills. Older children typically experience injuries from toys, pens, pencils, tree branches, and sports-related incidents. However, there is a gap in our knowledge regarding the frequency of injuries in children within our population.[16]

Injuries involving nonmetallic intraorbital foreign bodies (IOFBs) frequently occur in scenarios such as traffic accidents, accidental falls, bouncing injuries, or stab wounds during work or recreational activities. The primary factors contributing to these injuries are the high velocity and sharp nature of the foreign bodies. This study specifically investigated nonmetallic foreign bodies, including tree twigs/branches, chopsticks, bamboo toothpicks, wood sticks, glass, gravel, and plastic. Previous research has shown a higher incidence of such cases in children and young individuals, possibly attributed to falls during play and risks associated with carpentry work among the youth. In contrast, elderly patients constitute a smaller percentage, potentially due to less engagement in activities leading to these injuries.[16–19]

The clinical manifestations and potential complications depend on factors such as the material, size, shape, and placement of the foreign bodies.[20] The clinical presentation, treatment, and outcomes associated with orbital foreign bodies depend on the composition of the foreign body.[4,6] These objects can be categorized into three primary types based on their material: 1) metallic objects such as aluminum, copper, molten lead, steel, and iron; 2) inorganic non-metallic objects like plastic, glass, sand, concrete, rock, and other.; and 3) organic objects such as wood, plants, bones, grease, thorns, and vegetative materials.[4,14,16] In the context of penetrating foreign bodies within the orbit, the most common locations are the superior (26%), medial (30%), inferior (26%), and lateral (4%) orbital walls.[4]

Metallic foreign bodies, particularly those composed of materials such as iron, aluminum, copper, and lead, are frequently encountered and can be readily identified using computerized tomography (CT) scans. Conversely, nonmetallic foreign bodies pose diagnostic challenges in clinical settings due to their diverse compositions, complex shapes, and variable injury presentations, which can lead to them being overlooked or misdiagnosed. Despite technological advancements, the surgical removal of nonmetallic intraorbital foreign bodies (IOFBs) remains difficult and often associated with a relatively high rate of failure. Significantly, there is a scarcity of published literature regarding the management of nonmetallic intraocular foreign bodies (IOFBs), especially when compared to metallic IOFBs, despite the higher potential for serious complications.[21–23] The available literature is restricted to a handful of retrospective studies involving a limited number of cases.[24–27] Consequently, thorough examinations of cases with nonmetallic intraocular foreign bodies (IOFBs) are crucial for advancing comprehension and advancing clinical approaches for diagnosis and treatment in the future.[20]

To address these cases effectively, a thorough clinical assessment involving ultrasound and CT scans, along with examinations conducted under general anesthesia, is essential. The perioperative management of intraocular foreign bodies (IOFB) should adhere to a standardized protocol but also be customized to each patient's specific needs. This approach includes determining the necessity and timing of surgical intervention, deciding on the number of surgical stages required, and addressing any potential complications.[1]

The Key considerations in the assessment and treatment of such cases include Clinical Evaluation (Thorough

clinical assessment, including a detailed history and comprehensive eye examination, is crucial. Identify the nature, size, and composition of the foreign body. Evaluate the extent of ocular trauma and associated injuries); Imaging Studies (Utilize imaging modalities such as X-rays, CT scans, or MRI to precisely locate and characterize the IOFB. Assess the depth and proximity of the foreign body to ocular structures); Ophthalmic Examination (Conduct a detailed examination of the anterior and posterior segments of the eye. Assess visual acuity, intraocular pressure, and signs of inflammation or infection); Surgical Intervention (The primary approach often involves surgical removal of the foreign body to prevent complications. Consideration of the timing of surgery is crucial, balancing the urgency of removal with the patient's overall condition); Customized Treatment (Tailor the treatment plan to the specific characteristics of the IOFB, including its size, composition, and location. Address any associated injuries to ocular structures); Complication Management (Be vigilant for potential complications such as infection, inflammation, or damage to vital ocular structures. Administer appropriate prophylactic antibiotics to prevent infection); Follow-Up and Rehabilitation (Schedule regular follow-up visits to monitor the patient's progress post-surgery. Consider rehabilitation measures, such as visual therapy, to optimize visual outcomes); Multidisciplinary Approach (In complex cases, involve a multidisciplinary team, including ophthalmologists, radiologists, and possibly neurosurgeons, to ensure comprehensive care; Patient Education (Educate the patient about the importance of compliance with medications and follow-up appointments. Provide information on potential long-term effects and rehabilitation options); Research and Advancements (Stay updated on the latest research and advancements in the field of ocular trauma and IOFB management).[1]

The characteristics of nonmetallic IOFBs, including symptoms, visual prognosis, and the necessity for surgical intervention, depend on the specific composition of the foreign object. Comprehensive imaging is crucial for formulating a surgical plan, considering factors such as the structure and location of the foreign body, as well as the presence of secondary infections. Larger foreign bodies are generally easier to diagnose and remove, while smaller ones pose a greater risk of missed diagnoses and challenging surgical procedures.[28]

For suspected IOFB cases, thorough ophthalmic and imaging examinations are essential to assess the foreign body's location, size, and material, as well as to evaluate potential surgical damage. Additionally, a full understanding of treatment options and prognosis is crucial, with equal consideration given to the opinions of both the ophthalmologist and the patient in making final treatment decisions.[20]

Precision and accuracy are imperative in the emergency department. The preferred initial diagnostic imaging method for assessing the location of intraorbital lesions (intraconal, extraconal, or intraocular) and determining the subsequent treatment plan is a 3D Head CT scan.[5,29] The main approach for treating patients with intraorbital foreign bodies involves removing the foreign body. The management of intraocular injuries varies based on factors such as the involvement of the optic nerve or the neurovascular bundle of the retina and the severity of the injury.[5]

Small nonorganic intraorbital foreign bodies that are relatively inaccessible can often be left in place without significant subsequent complications. However, larger intraorbital foreign bodies pose a considerable risk to adjacent structures and have the potential for intracranial extension, depending on their depth. In such cases, surgical removal should be considered,

necessitating careful and meticulous treatment planning and execution.[29,30]

The decision to proceed with surgery must be personalized, taking into account the surgeon's evaluation of the potential surgical risks compared to the risks associated with retaining the foreign body, which may result in delayed complications like infection and fistula formation. Surgical removal of the foreign body is recommended when patients exhibit neurologic compromise, mechanical restrictions affecting eye movements, acute or chronic infections, or chronic suppurative reactions to the foreign body.[30]

The primary complication associated with retained intraorbital foreign bodies is infections. Therefore, patients with intraorbital foreign bodies should receive tetanus prophylaxis and broad-spectrum antibiotics that can penetrate the blood-brain barrier due to the proximity to the central nervous system.[31] In suspected intracranial infections, a common recommended antibiotic regimen involves high-dose third-generation cephalosporin and vancomycin.[8]

When foreign bodies are situated in the anterior segment without penetrating the eye globe, and the patient initially shows good visual acuity, the outlook for visual acuity is typically more positive. Research indicates that in cases where there is no globe involvement, no subsequent loss of vision has been observed.[8]

The diagnosis and treatment of nonmetallic IOFBs are complex processes with diverse conditions and potential complications. Organic foreign bodies, predominantly encountered in such cases, contribute to varying clinical manifestations. CT imaging aids in identifying foreign body materials, although foreign objects may be occasionally misdiagnosed. MRI can assist in detecting wooden foreign bodies and grease. Surgical treatment for IOFBs is intricate and may necessitate a multidisciplinary team approach. The complete removal of residual organic IOFBs is crucial to prevent infections and inflammation.[32]

The research describes an uncommon and intriguing case involving a pediatric patient with an intraorbital foreign body (IOFB) that penetrated the orbital cavity and extended into the temporal lobe. Medical terminology is used appropriately, balancing technical details with readability. The report explicitly mentions the absence of complications such as intraconal or intraocular lesions, as well as intracranial, subdural, or epidural hematomas. This information is crucial for understanding the extent of the injury and its potential complications. The use of 3D Head CT scan for diagnostic evaluation is highlighted as an essential and precise tool for determining the location of the IOFB and therapeutic planning. The head scan precisely locates the foreign body, assesses affected bone structures, and rules out various types of lesions or hematomas. The study emphasizes the importance of individualized treatment decisions based on the risks and benefits of surgical removal of IOFBs. The discussion on infection as a common complication of retained IOFBs and the recommended antibiotic regimen adds valuable insights to clinical practice.

The case illustration involving a plastic foreign body penetrating the orbital cavity and reaching the temporal lobe presents a unique and unusual scenario. The study underlines the significance of 3D Head CT scans in managing IOFB cases, providing a valuable perspective on diagnostic tools in this context. The emphasis on personalized treatment decisions based on individual patient factors adds a novel aspect to the discussion of IOFB management.

The study primarily focuses on a single case, which limits the generalizability of the findings. The study mentions the predominance of these injuries in young individuals but does not provide detailed demographic information, such as age groups, gender distribution, or socioeconomic factors. Including a larger

sample or additional cases would enhance the robustness of the conclusions. While the study discusses the importance of precise action in the emergency department, it would benefit from more detailed information about the surgical procedure and post-operative care, which could provide additional guidance for healthcare professionals. The paper briefly mentions the outcomes of IOFB treatment without providing comprehensive data or follow-up information on the presented case, making it challenging to assess the long-term prognosis and potential complications. The emotional and psychosocial aspects of the patient and her family, especially considering the young age of the child, are not discussed. The impact of the incident on the child's well-being and potential psychological support measures are relevant considerations.

CONCLUSION

Pediatric cases involving intraorbital Foreign Bodies (IOFBs) are infrequent but require immediate attention as surgical emergencies. The initial management in the emergency room must be conducted with precision and accuracy. Early diagnosis through the use of a 3D Head CT Scan is pivotal for determining the IOFB's location and understanding the anatomical structures involved. This timely diagnosis enables healthcare professionals to make immediate treatment decisions, thereby reducing the risk of complications.

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CONFLICT OF INTEREST

This study does not involve any conflicts of interest.

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AUTHOR CONTRIBUTION

YJF conceived and designed the study, collected and analyzed the patient's clinical data, and wrote the initial draft of the case report. AS provided critical input in diagnosing and treating the patient, reviewed and revised the manuscript, and contributed to the intellectual content. LZS performed the literature review and introduction research, helped in manuscript editing, and assisted in obtaining patient consent and data. DS supervised the entire case report, ensured compliance with ethical standards, coordinated among authors, and finalized the manuscript for submission.

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REKONSTRUKSI DAN ESTETIK

USING OF NEGATIVE WOUND PRESSURE THERAPY (NPWT): A CASE SERIES OF WOUND DISRUPTION AS A COMPLICATION OFA CAESAREAN SECTION

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ABSTRACT

Introduction: Wound disruption following caesarean sections is a common issue that can increase maternal mortality and morbidity. Several factorshave been identified, including maternal, procedural, and antibiotic factors. The re-suturing method, primer, and secondary suture often fail,causing recurrent and delayed healing.
Case Illustration: CASE 1: A 26-year-old woman, 7 days post-caesarean section, presented with a wet wound and yellowish serous fluid. Three weeks later, wound dehiscence occurred despite re-debridement and re-suturing. Subsequent installation of VAC resulted in granulation tissue and re-epithelialization. CASE 2: A 32-year-old woman, 14 days post-caesarean section, complained of weakness and pus in the surgical wound. Upon examination, a red-yellowish fluid was found, indicating wound dehiscence. Re-debridement and VAC installation led to the formation of granulation tissue and re-epithelialization.
Discussion: VAC is the new wound care technique that suctions or collects excess exudate thatabsorbent gauze cannot accommodate. In comparison, absorbent gauze is limited in its capacity to absorb the fluid that produced in wounds. An innovation where the use of VAC, which has anegative pressure function, can stimulate granulation tissue to form and can bind the edges of the wound so that it can close naturally.
Conclusion: In instances of wound disruption following surgery, such as in the case of a caesarean section, it may be prudent to contemplate re-debridement followed by re-suturing. VAC presents itself as a viable alternative for managing wound dehiscence until the formation of granulation tissue.

Highlights:

1. Surgical site infection during caesarean section can cause complications, thereby increasing maternal mortality and morbidity, especially in groups at risk.
2. VAC therapy can stimulate granulation tissue formation so that primary wound junctions occur.
3. VAC shows its ability to close wounds entirely within 3-4 weeks

INTRODUCTION

Surgical Site Infection (SSI) is an infection at the surgical site that occurs burdens for patients. Patients who experience SSI are estimated to have three times more readmissions with significantly higher costs within 30 days after surgery. Surgical wound infections can be classified based on the depth of the tissue involved, starting from the outer and subcutaneous to deeper tissue, including fascia and muscle layers. The infection can spread to organs and body cavities.[1] Studies show that the most common pathogen causing SSI is *Staphylococcus aureus,* which occurs in 15%-20% of cases.[2]

A survey conducted in the UK revealed that Surgical Site Infection (SSI) ranked as the third most common cause of Healthcare-Associated Infections (HAIs).[3] According to data from the Centers for Disease Control and Prevention (CDC) in 2015, there were 110,800 cases of SSI reported in inpatient surgical procedures, contributing a percentage of 20 percent of all HAIs cases. Even though there have been developments in improving operating room ventilation, controlling infections, providing prophylactic antibiotics, as well as developing sterilization methods and surgical techniques, SSI still contributes to the cause of morbidity and mortality in patients with a mortality risk of up to 75%.

Infection is a risk factor for disturbances in wound healing. Continuous inflammation due to prolonged cleaning of microbes can cause chronic wounds and failure to heal.[4] Wounds will experience delayed re-epithelialization, leading to the formation of hypertrophic scars due to the accumulation of abnormal extracellular matrix.[5]

Based on a survey in the UK, patients with SSI will experience prolonged hospitalization of up to 9.7 days, which causes an additional cost burden than non-infected patients, with additional costs reaching £5,249. Cost burdens include expenditures on diagnostics, inpatient care, staffing, and pharmaceuticals, encompassing heightened antibiotic usage, increased utilization of wound dressings, and additional therapeutic interventions.[3]

Surgical Site Infection (SSI) is a complication that can occur after a caesarean section, which is associated with high maternal morbidity and mortality rates in subsequent pregnancies.[6] Numerous risk factors contribute to the occurrence of SSI post-caesarean section, encompassing individual, pregnancy-related, intrapartum, and procedural considerations. Personal factors include maternal age, obesity, maternal comorbid diseases, history of miscarriage, and history of previous caesarean section. Pregnancy and intrapartum factors include hypertensive disease, gestational diabetes mellitus, multiple pregnancies, premature rupture of membranes, and chorioamnionitis. Procedural factors indicate an increased risk of delivery without prophylactic antibiotics, emergency delivery, the need for blood transfusions during surgery, prolonged labor duration, and operating environments with poor sanitation.[2] An infection in a post-caesarean wound can lead to various complications, one of which is wound dehiscence.

Many preventive measures are available to mitigate Surgical Site Infection (SSI) and associated complications following caesarean sections, spanning perioperative, intraoperative, and postoperative phases. The closure technique employed for the wound significantly influences the incidence of wound dehiscence. Conventionally, wound closure typically involves suturing, utilizing staples, or a combination of both. However, such techniques still carry the risk of wound dehiscence.

Vacuum Assisted Closure (VAC) therapy is widely utilized for managing various types of wounds, including those in the abdomen, fractures, sternum, and as prophylaxis for closed incisions.[7] Studies have consistently shown that VAC therapy significantly reduces the incidence of Surgical Site Infection (SSI), wound dehiscence, seroma formation, and skin necrosis by facilitating primary wound

closure. Its effectiveness extends to managing wound dehiscence following caesarean sections, thereby lowering the risk of SSIs and subsequent wound dehiscence.

CASE ILLUSTRATION

Case 1

A 26-year-old housewife, G1 P1A0, with a gestational age of 38-39 weeks, underwent complete prenatal care with no uterine abnormalities detected. The patient opted for a caesarean section due to indications of prolonged labor on March 3rd, 2023. She had a height of 155 cm and a body weight of 75 kg, resulting in a BMI of 31, classified as Obesity level I. Prior to surgery, the patient received prophylactic antibiotic cefazolin 2g (first-class cephalosporin). No intraoperative abnormalities were noted. The baby was born immediately crying with an Apgar score of 9, weighing 3100 g, and clear amniotic fluid. The patient and baby were discharged two days after the caesarean section.

Figure 1. Post Caesarian Section (A) First week, (B)Third week, (C)Third days after the first re-debridement, (D) Second re-debridement and VAC installed, (E)Second weeks after VAC installed, (F) Third weeks after VAC installed, (G)First weeks after VAC removed

As a follow-up to the surgery, a week later, the patient returned for wound inspection with the main complaint of a burning sensation in the wound accompanied by yellowish fluid discharge from the surgical wound. The patient reported no fever, weakness, or nausea. Vital signs of the patient were as follows: blood pressure 120/80 mmHg, heart rate 80 bpm, respiratory rate 22 times/minute, and body temperature 37.1°C. Based on a complete blood test, the patient's hemoglobin level was 12 g/dL, leukocytes were 10,200 µ/L, and platelet count was 345,000. The patient was observed in the hospital for wound management.

Based on the observations in the first-week post-surgery, the patient's wound exhibited a wet dressing accompanied by yellowish serous fluid with a positive *Staphylococcus aureus* culture. The patient received a course of co-amoxiclav injections, 3 x 1g for seven days. The wound fluid was cleaned using absorbable gauze every two days while maintaining wound moisture. In the second week after wound care (three weeks after caesarean section), dehiscence was discovered with open wound edges and stretched stitches, leading to re-debridement and re-suturing. Dehiscence recurred after re-debridement and re-suturing of the wound on the third day, with a positive *Staphylococcus aureus* culture. Re-debridement was performed first. On the third day after the initial re-debridement, the wound was re-debrided, and a decision was made to install a VAC. In the second week after VAC installation, the wound turned reddish, indicating the beginning of revascularization. By the third week after VAC installation, granulation tissue started forming in the

wound. In the first week after VAC removal, the wound appeared closed.

Case 2

The 32-year-old woman is a teacher, G2P2A0, with a gestational age of 39-40 weeks. The patient's prenatal history is complete, and there were no visible abnormalities during the pregnancy. A caesarean section was performed on March 3rd, 2023, due to indications of premature rupture of membranes for more than 24 hours. The patient's height is 162 cm, with a body weight of 63 kg, resulting in a BMI of 24 (standard classification). A preoperative prophylactic antibiotic, 2g cefazolin injection (first-class cephalosporin), was administered. During the operation, greenish amniotic fluid was observed. The baby cried immediately after birth, with an Apgar score of 8-9. Three days post-caesarean section, the patient was discharged home.

Figure 2. Post Caesarian Section (A) First day, (B) Third day, (C) Re-debridement, (D) VAC installation, (E) First week after VAC installation, (F) Second week after VAC installation, (G) Third week after VAC installation, (H) First treatment after VAC removal, (I) First week after VAC removal

Two weeks after the caesarean section, the patient came for wound control with the main complaints of weakness and the presence of yellowish fluid coming out of the wound in small quantities. There is no fever or pain in the wound. The patient's vital signs are blood pressure 127/60 mmHg, heart rate 75 bpm, respiratory rate 22 times/minute, and body temperature 36.8°C. A complete blood examination shows a hemoglobin level of 12 g/dL, 9800 µ/L leukocytes, and platelets 298,000. The patient was then hospitalized for observation and wound care. Wound care is carried out every two days. A culture was carried out on the wound specimen. The patient was hospitalized for observation and wound management.

Based on observation results in the second week post-surgery, wound dehiscence with yellowish fluid was noted, and the *Staphylococcus aureus* culture was positive. A regimen of co-amoxiclav injection, 3×1 g for seven days, was administered alongside wound treatment. On the second day post-wound treatment, increased exudate production and widening of wound dehiscence prompted the decision to install a Negative Pressure Wound Therapy (NPWT) system, specifically the Negative Pressure Wound Therapy (NPWT) in the two cases mentioned.

During the first week after NPWT installation, exudate and wound area decreased. In the second week, wound edges appeared to draw closer, with vascularization evident. By the third week, visible granulation

tissue formation was observed. Upon VAC removal, the wound appeared fully closed and healed. Subsequent follow-up in the first-week post-VAC removal showed primary wound closure and no recurrence of wound dehiscence.

The VAC type used was Negative Pressure Wound Therapy (NPWT) in the two cases above. Before installing a VAC, the wound is first cleaned thoroughly with normal saline. The black sterile foam was used to bandage wounds. According to Agarwal et al. (2019), VAC therapy for thoracic or abdominal wounds can be used with lighter black foam (Polyurethane ether) with a 400-600 mm pore size. This foam provides an even distribution of negative pressure throughout the wound bed.[8] A fenestrated evacuation tube is mounted on the foam and connected to a vacuum pump. Then, the foam and pipe are covered with adhesive to keep the wound water and airtight. The pressure used was 120 mmHg in continuous mode, and the foam was replaced, and the wound was evaluated weekly.

DISCUSSION

Surgical Site Infection (SSI) is an infection that occurs within 30 days after surgery. SSI can be classified based on the depth of tissue involved into superficial incision SSI, deep incision SSI, and cavity/organ SSI. The risk factors for SSI are not only related to the wound but are also influenced by perioperative-related and individual factors. In Case 1, the patient's obesity, classified by their BMI, poses a specific risk factor for SSI following caesarean section. The indication for a caesarean section in case 2 wasdue to premature rupture of the membranes. A history of previous infection, which is visiblein the greenish amniotic fluid, is a risk factors responsible for surgical wound infection in the mother's caesarean wound. With the high number of caesarean deliveries and increasing inthe last ten years[9], delivery rooms have thepotential to have low sterility, thereby creating a risk of SSI after caesarean delivery in mothers.

The presence of SSI often leads to wound dehiscence, defined as total or partial separation of wound edges due to incomplete wound healing, primarily in the early stages of wound healing.[10] Wound dehiscence itself, if not handled properly, can cause various complications, one of which is persistent infection, which induces a prolonged inflammatory process, causing delayed wound healing. This excessive inflammatory process can stimulate fibrotic tissue, which can cause the accumulation of abnormal extracellular matrix, which leads to hypertrophic scars.[5]

Conventionally, the management of wound closure after a caesarean section generally uses the method of skin closure using sutures and staple closure.[6] However, the re-stitching method in case 1 did not show good results even after re-debridement three times, which resulted in the patient experiencing wound dehiscence again. Likewise, in case 2, after wound treatment, there was still a widening of the wound dehiscence and increased exudate production. Based on the series of wound treatments that were carried out, it turned out that the wound could not improve, so it was decided to undergo therapy using VAC.

Vacuum Assisted Closure (VAC) offers an alternative approach to wound management, utilizing negative pressure to prepare the wound site for natural healing or less invasive reconstructive treatment options.[11] It is a therapeutic technique within the negative pressure wound therapy (NPWT) system, applying subatmospheric pressure to reduce inflammation and stimulate granulation tissue formation.[12] NPWT efficiently removes necrotic tissue and wound secretions, stimulates granulation tissue production, reduces bacterial infection, and accelerates wound healing.[13]

The VAC system consists of a semi-occlusive adhesive cover, polyurethane foam sponge, fluid collection system, and suction pump. Its working mechanism encompasses four main mechanisms: macrodeformation,

fluid drainage, stabilization of the wound environment, and microdeformation.[14] These mechanisms are supported by clinical evidence demonstrating faster wound healing and reduced complications compared to conventional wound closure methods. They emphasize how VAC contributes to wound contraction, reduction of edema, and the promotion of angiogenesis and granulation tissue formation, all crucial for effective wound healing.

Subatmospheric pressure induces macrodeformation by promoting wound contraction, while polyurethane foam aids in pressure distribution and effective exudate absorption, ultimately reducing the wound's surface area.[14] Edema in wounds can suppress extracellular matrix cells, reducing cell proliferation essential for wound healing. With VAC, suction minimizes edema by removing extracellular fluid, increasing intravascular fluid velocity, and reducing intravascular hydrostatic pressure, thereby lowering intravascular fluid efflux and edema.[8] Reducing exudate in wounds also benefits tissue perfusion and can limit the depth of dead cells.[14,15]

The semi-occlusive polyurethane drape stabilizes the wound environment by acting as a semipermeable membrane, which maintains warmth and moisture while limiting microbial colonization and preventing further infections. This stability reduces the frequency of dressing changes, unlike traditional gauze dressings. Moreover, by minimizing the risk of recurrent Surgical Site Infection (SSI), wounds can heal without delays, thus preventing the formation of hypertrophic scars.[5]

Microdeformation, induced by the negative pressure generated by VAC at the interface between the wound and the foam, triggers shear stress, promoting cell deformation and enhancing wound tissue perfusion. This microdeformation process also stimulates angiogenesis, cell proliferation, and granulation tissue formation. Angiogenesis is facilitated by tissue hypoxia, leading to the release of nitric oxide (NO) and the expression of Vascular Endothelial Growth Factor (VEGF).[8] Experimental studies in animal models have consistently shown accelerated wound healing, with a significant increase in granulation tissue formation compared to gauze dressings.[16]

Cases 1 and 2 achieved complete wound healing in just 3-4 weeks, faster than the typical wound healing phase. The stimulation of granulation tissue formation facilitates the natural closure of the wound.

Furthermore, the use of VAC enhances patient and nursing staff comfort compared to traditional dressings, reducing the frequency of dressing changes, fluid leakage, and wound odor.[14,17] Despite potentially higher initial costs, the overall treatment cost using VAC is comparable to modern dressings. The long-term benefits of VAC therapy include accelerated healing, reduced complications, and minimized hospitalization time, making it a cost-effective option for wound management.

In addition, the use of Vacuum Assisted Closure (VAC) minimizes the risk of Surgical Site Infections (SSI) and reduces the likelihood of patient re-hospitalization.[15] VAC effectively cleans surgical wounds by continuously removing fluids such as blood, pus, and remnants of dead tissue using negative pressure. This reduction in bacteria and organic matter significantly decreases the risk of infection. Moreover, the negative pressure from VAC promotes the development of crucial granulation tissue, essential for proficient wound healing. Additionally, VAC contributes to reducing tissue swelling or edema surrounding the wound, thereby enhancing blood circulation to the wound site. Improved blood flow facilitates better oxygenation and nutrient delivery to damaged tissues, fostering accelerated healing. Furthermore, VAC's semi-occlusive design creates a warm, moist, and shielded environment for the wound, protecting it from external contaminants. These conducive conditions promote optimal wound healing, diminish infection risks, and

expedite the healing process.

The implementation of Negative Pressure Wound Therapy (NPWT) has shown promising results in reducing complications, expediting wound healing, enhancing patient comfort, and improving overall outcomes for post-operative wounds, including those from caesarean sections, while also reducing long-term costs.

This study underscores the importance of employing appropriate methods to treat wound infections, particularly post-caesarean section wound infections. It also explores patients' prenatal to delivery history to establish correlations between risk factors and surgical wound infections. A notable finding of this research is the effectiveness of Vacuum Assisted Closure (VAC) therapy in inhibiting secondary infections, especially among patients with high-risk factors. This highlights the potential of VAC therapy as a preventive measure against secondary infections.

The research monitors wound care in cases ranging from infection through dressing methods to VAC therapy, revealing improving wound healing outcomes. Further evaluation indicates no complications in these cases, with negative *Staphylococcus aureus* bacterial cultures. Consequently, Agarwal et al. (2019)[8] recommend wide adoption of VAC therapy, particularly in treating Surgical Site Infections (SSI). They argue that VAC therapy is a simple and more effective method compared to conventional dressings, reducing wound volume, depth, treatment duration, and costs[8]. However, the study's limitation lies in its small sample size, resulting in descriptive data prone to bias. Additionally, the absence of a control group prevents the assessment of method effectiveness and identification of risk factors in treating infected wounds post-caesarean section.

CONCLUSION

Wound dehiscence due to wound infection after caesarean section still often occurs in mothers, especially in at-risk groups. Inappropriate treatment can trigger persistent infections. These infections have a clinical impact on the wound-healing process. Persistent infections also create a heavier cost burden due to prolonged hospitalization. Therefore, in treating wound dehiscence after caesarean section, VAC can be considered as a definitive therapy to form primary wound junctions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest about research or writing until the publication of this paper.

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AUTHOR CONTRIBUTION

YJ has contributed to the planning and conceptualizing of the manuscript, ERM and DRK have contributed to data collection and analysis, GSW and ESR have contributed to the writing and revision of the manuscript, and HYLW approved this paper for publishing.

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REKONSTRUKSI DAN ESTETIK

A CASE SERIES AND LITERATURE REVIEW: MANAGEMENT STRATEGIES FOR RADIATION-INDUCED ULCERS OF THE CHEST

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ABSTRACT

Introduction: Radiotherapy as an adjunct to cancer treatment causes a high incidence of radiation-induced tissue injury, ranging from radiation dermatitis to severe osteoradionecrosis. Currently, no gold standard exists in the management of radiation injury. Various strategies ranging from modern wound treatment to surgical management have been studied.
Case Illustration: Three women presented with varying degrees of ulceration in the chest during or shortly following radiotherapy. Each case followed different approaches to management. One case solely received wound treatment, another received wound treatment and a sequestrectomy, and the third required surgical reconstruction of the chest wall and defect.
Discussion: Methods of wound treatment range from topical agents, barrier films and dressings, hydrogel and hydrocolloid dressings, miscellaneous treatments, and biodressings. Surgery is required in severe cases, particularly with osteoradionecrosis. This may include wound debridement, biopsy, chest wall stabilization, closure using various flaps, and potential breast reconstruction.
Conclusion: Radiation-induced ulcers of the chest pose a complex issue. Understanding effective treatment methods and key surgical principles is important for ensuring better outcomes. Further studies are needed to provide a complete guide to treatment.

Highlights:

1. Radiotherapy leads to a high occurrence of skin alterations and can advance to different levels of tissue damage, presenting challenges in treatment.
2. Management can be effective employing diverse wound treatment methods, although severe cases may necessitate surgical intervention.
3. Surgery takes into several key considerations to increase chances of success and tackle specific issues of chest wall instability and breast reconstruction.

INTRODUCTION

Radiotherapy serves as an essential adjunct to surgical tumor resection in breast cancer treatment, aiming to eradicate microscopic disease and reduce cancer recurrence. However, a significant challenge associated with radiotherapy is the high incidence of radiation-induced tissue injury, ranging from acute radiation dermatitis to severe osteoradionecrosis and radiation-induced sarcoma. Approximately 95% of radiotherapy patients experience some degree of skin changes attributed to radiation injury. DNA damage caused by the radiation

primarily affects the proliferative phase of the cell cycle. This may explain how the earliest symptoms of radiation toxicity typically occur in cells with high turnover rates, such as skin and mucosa.[1,2]

Currently, no established gold standard exists for the management of radiation-induced tissue injuries. This is attributed to conflicting results from clinical trials and a scarcity of high-quality, large-sample studies.[2,3] Additionally, there is no universally applicable surgical approach and when indicated, requires careful consideration of factors such as the location, shape, and size of the affected tissue, as well as the choice of the most suitable flap for desired outcomes.

In this report, we present three cases of women who developed varying degrees of ulceration in the chest region during or shortly after undergoing radiotherapy for breast cancer. These cases highlight different approaches to management, ranging from wound treatment alone to surgical reconstruction of the chest wall and defect. By examining these cases and reviewing the available evidence, we aim to provide valuable insights into effective treatment strategies for radiation-induced ulcers of the chest.

CASE ILLUSTRATION

Case 1

The patient, a 48-year-old female foreigner with recurrent breast cancer, underwent radical mastectomy, split-thickness skin graft, chemotherapy, and radiotherapy. Following completion of radiotherapy while continuing capecitabine chemotherapy, she developed ulcers on her right thoracic region. The wound was initially treated with silver sulfadiazine hyaluronic acid cream, and as the wound bed improved, non-adherent hydrophilic foam dressings were applied. Subsequently, signs of epithelialization appeared, and after three months of treatment, the patient was able to independently continue wound care upon returning to her home country.

Figure 1. (A) Case 1 initial clinical presentation showing moist desquamation, (B) 3-month follow-up with nearly complete epithelialization.

Case 2

In the second case, a 51-year-old female patient underwent a right mastectomy, chemotherapy, and radiotherapy, while also receiving anastrozole for hormonal therapy. Following the completion of radiotherapy, she presented with ulcerative radionecrosis of her right chest. The wound exhibited a large, ulcerated mass with necrotic tissue, slough, and pus. Initially, local debridement was performed, and hydrogel dressings were applied for further autolytic debridement. However, during routine follow-up appointments, the wound exhibited hypergranulation and serous discharge. By the third month, exposed bone became visible, prompting a sequestrectomy. Following the procedure, an antibiotic and hydrocortisone cream mixture was applied, along with tulle

dressings. After nearly six months of treatment, the wound eventually healed well, and the patient experienced no further complications.

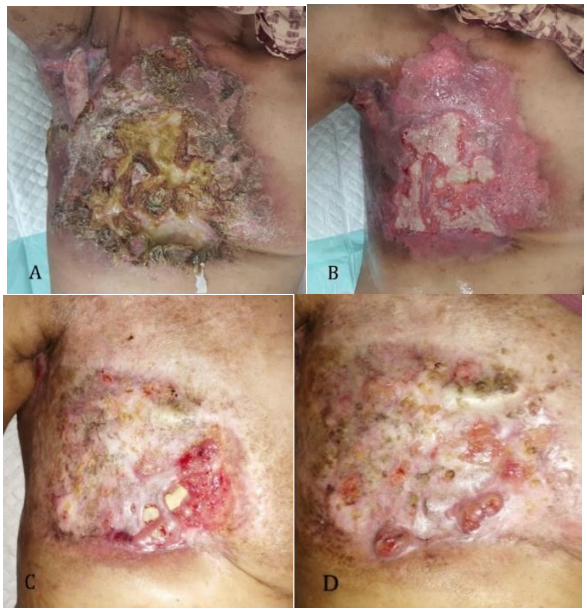

Figure 2. (A) Case 2 clinical presentation showing necrotic tissue, slough, and pus, (B) after local debridement, (C) granulation tissue and exposed bone at 3-month follow-up, (D) the wound nearly fully healed at five months.

Case 3

The patient, a 34-year-old female with recurrent breast cancer and a history of left mastectomy, underwent chemotherapy and radiotherapy. Upon presentation, she exhibited ulcerative wounds on her left chest, containing necrotic tissue, slough, and pus. Initially, the wound was treated with dialkylcarbamoyl chloride (DACC)-coated dressings until the completion of radiotherapy. Subsequently, hydrogel dressings were employed. By the third month, the wound had significantly enlarged, measuring approximately 15x20cm, with exposed second to fourth left costae indicating osteoradionecrosis. Surgical intervention was deemed necessary, involving the removal of necrotic tissue and segments of the second to fourth costae. Reconstruction ensued, utilizing sternal wire, a 15x15cm surgical mesh, a latissimus dorsi (LD) flap, and split-thickness skin grafts. During follow-up, the graft achieved approximately 99% viability, resulting in a small defect and minimal seroma presence. Despite this, the wound exhibited no signs of improvement over three months and necessitated closure with a transpositional flap from the right chest, alongside the maintenance of a drain for two weeks. Following seven months of treatment, the wound healed successfully, and the patient experienced no further complications.

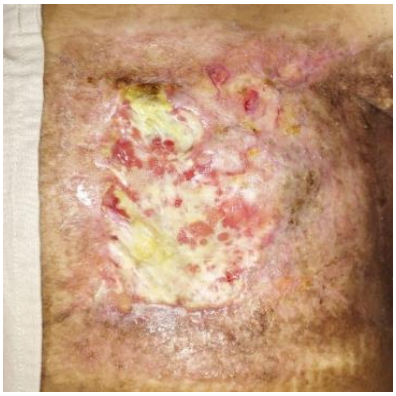

Figure 3. Case 3 displaying exposed bone on the chest after three months of treatment.

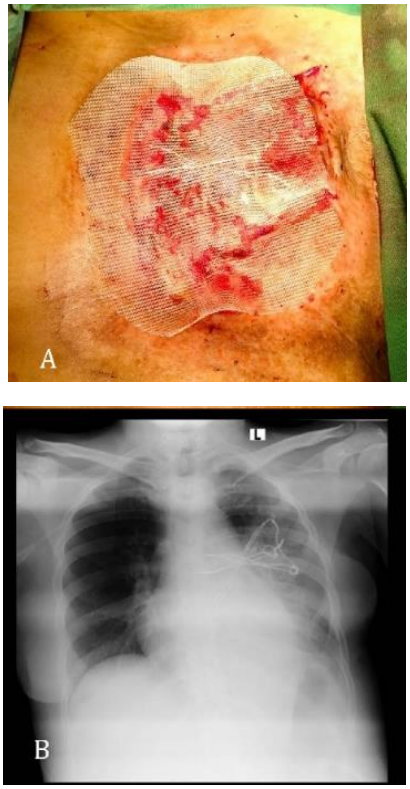

Figure 4. (A) Intraoperative view of the surgical mesh (B) Postoperative X-ray demonstrating sternal wires.

Figure 5. (A) Small defect post-treatment (B) Closure achieved with a transpositional flap

DISCUSSION

Radiation dermatitis manifests in acute and chronic stages, with acute changes occurring within 90 days of treatment initiation. Severity is often graded using the Common Terminology Criteria for Adverse Events (CTCAE).[1,2] Grade 1 presents with pruritus, epilation, scaling, and depigmentation, while grades 2 and 3 exhibit moist desquamation, especially with cumulative radiation doses exceeding 40 Gy, increasing the risk of infection and pain. Untreated grade 4 changes can lead to progressive ulcerations and fibrosis.[3,4] Chronic changes, appearing months to years post-exposure, include telangiectasia, epidermal thinning, dermal atrophy, pigmentation changes, fibrosis, edema, keratosis, and necrosis.[1,5,6]

Table 1. Common Terminology Criteria for Adverse Events (CTCAE) version 5.0

Grade	Clinical Description
1	Faint erythema or dry desquamation
2	Moderate to brisk erythema; patchy moist desquamation, mostly confined to skin folds and creases; moderate edema
3	Moist desquamation in areas other than skin folds and creases; bleeding induced by minor trauma or abrasion
4	Life-threatening consequences; skin necrosis or ulceration of full thickness dermis; spontaneous bleeding from involved site; skin graft indicated
5	Death

The most severe forms of localized radiation injury include osteoradionecrosis and radiation-induced sarcoma. Osteoradionecrosis is characterized by exposed irradiated bone failing to heal over three months without tumor evidence.[7] It typically presents with slowly worsening skin ulceration, sometimes accompanied by extensive soft tissue changes. While most commonly found in the mandible, osteoradionecrosis may also develop in other regions such as the chest wall. In cases of full-thickness necrosis of the chest wall, pathologic rib fractures may cause discomfort and instability of the chest wall. Tissue necrosis progresses due to compromised vasculature, inflammation, and infection, potentially exposing thoracic viscera and causing complications like empyema and septicemia if left untreated.[8,9]

Preventing radiation-related tissue damage is crucial, necessitating communication between surgeons and radiation oncologists to minimize complications. Additionally, Ethical considerations in clinical decision-making, as well as the role of patients in the treatment

process, including patients' rights to make decisions and understand information, and relevant bioethical principles, are essential. Prevention of radiation injury in breast cancer involves a series of strategies to reduce the risk of injury before, during, and after radiation therapy. Before Radiation Therapy, providing patients with information about potential side effects that may occur during and after radiation therapy, as well as steps that can be taken to reduce the risk of injury. Evaluate the skin before radiation therapy to identify areas vulnerable to radiation dermatitis. Good skin care before radiotherapy can help reduce the risk of injury. and ensuring the patient's overall health and identifying factors that may increase the risk of radiation injury, such as obesity, smoking history, and certain skin conditions. During Radiation Therapy, using advanced radiotherapy techniques, such as three-dimensional conformal radiotherapy (3D-CRT), intensity-modulated radiation therapy (IMRT), or volumetric modulated arc therapy (VMAT), to control radiation dose and minimize exposure to surrounding healthy tissues. Utilizing appropriate skin care, such as non-adherent hydrophilic cream, to protect the skin from radiation effects and reduce the risk of radiation dermatitis. Conducting regular monitoring during radiation therapy to detect changes in the skin or other symptoms that may require further intervention. After Radiation Therapy, providing continued care to reduce symptoms of radiation dermatitis, such as using topical corticosteroid cream or hydrogel. Providing patients with information about skin care needed after radiation therapy, as well as signs and symptoms to watch for. and Conducting long-term monitoring to detect long-term complications of radiotherapy, such as osteoradionecrosis, and providing appropriate intervention if needed.

When planning radiotherapy, factors like timing, dosage, fractionation, and techniques such as three-dimensional conformal RT (3D-CRT), intensity-modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT), and brachytherapy are vital for dose control.[10,11] Utilizing topical agents and dressings as preventive measure may not only reduce the occurrence of skin and tissue-related complications, but also reduce the severity of injuries sustained. Consequently, this may represent a more efficient and cost-effective strategy in patient management. Several preventive treatments with the most promising evidence include the use of mometasone furoate and betamethasone topical corticosteroids, polyurethane and silicone-based polyurethane films, photobiomodulation (low-level laser) therapy, topical olive oil, and oral enzyme mixtures. Early application of these treatments has shown to reduce skin changes incidence and severity.[2,3] Unfortunately, the reported cases did not receive any preventive treatment prior to radiotherapy.

Management of radiation dermatitis and osteoradionecrosis remains a challenge for many physicians. Conflicting results among studies and the lack of high-quality evidence further complicate the issue. To the authors' knowledge, this is the first report focused on management strategies published in Indonesia. Furthermore, as injuries often progress and manifest as a spectrum, it can be challenging to decide between treatment approaches. A comprehensive report and discussion encompassing both surgical and non-surgical treatment options may offer valuable insights for clinicians. While conservative treatments and modern dressings may suffice for some cases, severe instances, such as illustrated in case 3, may require surgical intervention.

This report demonstrates the use of topical agents, namely silver sulfadiazine hyaluronic acid cream and an antibiotic and hydrocortisone cream mixture. Some creams and ointments may help reduce skin inflammation caused by radiation. They are often utilized for minor cases and low-resource settings. Several topical non-steroidal agents and corticosteroids have

been expected to decrease inflammation in radiation dermatitis and are often considered a simple treatment option in limited settings.[2] Silver-containing dressings have long been utilized as burn dressings and noted primarily for their effectiveness against gram-positive and gram-negative bacteria, as well as some fungal infections. However, silver dressings have yet to demonstrate improved healing rates for radiation-induced tissue injuries. Limited evidence, however, suggests they may alleviate pain and itching in patients.[3] Hyaluronic acid preparations have been studied for their effectiveness in preventing radiation dermatitis, show promise for treatment. However, other non-steroidal agents or corticosteroids have demonstrated minimal benefit.[2] Hydrocortisone was specifically used in case 3 after the patient developed hypergranulation tissue. Topical steroids have shown effectiveness in cases of aberrant wound healing resulting in hypergranulation tissue.[12,13]

During radiotherapy, barrier films and dressings are usually suggested for prevention. Recent studies have explored their role in managing skin conditions. In this report, non-adherent hydrophilic foam dressings were applied to mildly exudative wounds with moist desquamation. Absorbent foam dressing is preferred over creams and standard wound care. Silicone-based polyurethane film dressings can be an alternative for non-exudative wounds. They are waterproof and transparent, facilitating easy care and assessment without removal. Although mainly for prevention, they may also be effective in managing wounds.[2,3]

Hydrogel and hydrocolloid dressings are utilized for maintain skin moisture in severe radiation skin problems. Hydrogel was applied in cases 2 and 3 for autolytic debridement of necrotic tissue and slough. However, evidence shows conflicting results regarding healing rates compared to other methods of care (e.g., gentian violet dressings, water-based spray, dry dressing). A silicone-based topical gel forms a thin, flexible, semi-occlusive, waterproof dressing that allows gas permeability. Studies have confirmed its efficacy in the prophylaxis of radiation dermatitis and improving specific clinical outcomes (e.g., erythema, itch, pain, burning sensation, inflammation, and hydration) when used as treatment in patients who have developed radiation dermatitis.[14]

There are still many alternatives worth mentioning that have not been covered in these cases. Studies have explored the possible effects of various miscellaneous therapies. Henna-containing ointment, lianbai liquid, hydrotherapy, and an emulsion were found to be effective in managing symptoms, but further research is required to warrant their use.[2]

Biodressings, described as conventional fibers combined with bioactive molecules such as growth factors and stem cells, are primarily reserved for use in severe cases of radiation dermatitis. They represent highly advanced biomaterials that have been a key focus of recent development. Stem cells derived from placental membrane and lipoaspirates have shown effectiveness in treating chronic radiation-induced injuries, even in cases where other modalities have failed.[15,16] Additionally, a combination of stem cell-released molecules from various types of skin stem cells has demonstrated efficacy in acute radiation dermatitis, leading to significant symptom reduction and complete wound healing.[17] Very few studies have utilized platelet rich plasma, although it may provide accelerated wound healing.[18] Other notable dressings yielding significant results include foam dressings containing epidermal growth factor, gauze impregnated with granulocyte-macrophage colony-stimulating factor, and irradiated human amniotic membrane.[3,19] Novel approaches gaining attention include functional hydrogels with complex properties, photoresponsive hydrogels combined with light-based therapy, and hydrogels integrated with biopolymers.[3,20]

Patients with osteoradionecrosis should undergo surgical treatment with the primary

goals of eliminating infection, excising all damaged tissue, and providing stability to the chest wall during reconstruction. Surgical intervention should involve the removing infected tissue and skin affected by radiation to facilitate proper healing. It is important to reduce the bacterial load of soft tissue as much as possible before surgical resection, which can be achieved through mechanical, enzymatic, or maggot debridement therapy. Biopsy of tissue margins is necessary to identify possible cancer recurrence or Marjolin's ulcer. Although a frozen section is recommended, it cannot detect changes in bony margins and may miss infiltrating breast cancer that can only be identified by permanent pathology.[8,9]

Surgical treatment options may include no reconstruction, prosthetic reconstruction, or biological reconstruction. In Case 2, wound healing was achieved through a simple bedside sequestrectomy and continued wound care. Full-thickness resection of the chest wall may lead to loss of chest wall rigidity, causing paradoxical respiration and ineffective respiratory effort. Stabilization of the chest wall is particularly recommended in sternectomy, large anterior and anterolateral defects, and resection of >3-4 ribs. A rigid prosthetic chest wall reconstruction can provide mechanical support, often accomplished using mesh, sometimes combined with methyl methacrylate or rib plating devices. In our case, mesh and sternal wires provided adequate stabilization of the chest after the removal of the second to fourth costae. However, using a prosthetic device increases the risk of infection, especially in contaminated wounds. Biological meshes, such as bovine acellular matrix, may decrease the risk of infection but generally provide inferior mechanical support.[8,9] Contaminated wounds of the thoracic wall can also be reconstructed using a thick musculocutaneous flap alone.[21]

Reconstruction of the resected area must consider the size and location of the tissue defect. Axial-pattern flaps such as pectoralis major, latissimus dorsi (LD), and upper rectus abdominal musculocutaneous flaps may be utilized in chest wall reconstruction. While a latissimus dorsi musculocutaneous flap presents minimal donor site problems compared to the rectus abdominal musculocutaneous flap, these flaps carry the risk of failure when radiation affects the nutrient vessel of the flap or damages the muscle itself. Free flaps may prove useful when axial-pattern flaps are at risk of failure, a flap has been previously utilized, or the defect is too large to cover with the flap. However, it is essential to consider the quality of vessels in free flap surgery, as certain flaps can damage blood vessels and lead to issues at the donor site. Alternatively, perforator flaps receiving blood supply from isolated perforating vessels may provide adequate coverage when the ulcer is relatively small and the perforator vessel and flap are outside the radiation field.[9,21]

Breast reconstruction commonly utilizes the Latissimus Dorsi (LD) musculocutaneous flap, free or pedicled transverse rectus abdominis musculocutaneous (TRAM) flaps, deep inferior epigastric perforator (DIEP) flaps, and omental flaps. While an omental flap may be a versatile biological implant, the need for intraabdominal surgery poses increased risk. Implant-based breast reconstruction may be possible but carries the added risk of infection and may not be suitable with a mesh already in place.[8,9,22]

Although there was no postoperative infection, our patient developed minimal seroma. Seroma is a common complication in many surgical procedures but is notably frequent in breast surgeries. Management may include serial aspirations, sclerosing agents in the seroma cavity, surgical marsupialization or excision of the seroma capsule, and drainage.[23]

Varying degrees of radiation-induced tissue injury, ranging from radiation dermatitis to osteoradionecrosis, require different therapeutic approaches. Prevention is the ideal initial approach; however, the

incidence of radiation-induced ulcers remains a complex issue. Some of the most promising treatments include foam dressings, silicone barrier films, and film-forming topical gel. Novel therapies include biodressings with stem cells, epidermal growth factor, granulocyte-macrophage colony-stimulating factor, and functional hydrogels, have also shown potential. Despite these advancements, simpler and more affordable options can still be utilized. Surgical intervention becomes necessary in more severe cases, particularly those involving osteoradionecrosis. Although various surgical options exist, adhering to key principles in the resection and reconstruction of the chest wall will ensure a better outcome. However, conflicting results and minimal available evidence suggest further studies are necessary to provide a comprehensive treatment guideline.

Management actions for radiation dermatitis and osteoradionecrosis can significantly impact the quality of life of patients. Here are some ways in which these management actions can affect patients' quality of life. Management actions such as the use of topical creams or gels, proper wound care, and other medical interventions can help reduce painful and disruptive symptoms such as itching, pain, and inflammation on the affected skin. By reducing physical symptoms and discomfort associated with radiation dermatitis and osteoradionecrosis, these management actions can help improve patients' psychological well-being. Patients may feel more comfortable and have lower levels of stress. In cases of osteoradionecrosis where surgical intervention may be necessary, proper management actions can help accelerate the healing process and physical recovery of patients after surgical procedures. This can improve patients' ability to perform daily activities and enhance overall quality of life.In some cases, effective management actions can help improve the function of tissues affected by radiation, such as the skin and surrounding soft tissues. This can help patients better navigate daily life and reduce the negative impact of the condition. Additionally, management for radiation dermatitis and osteoradionecrosis can effectively enhance treatment success, reduce infection risk, and improve the affected tissue's condition by optimizing treatment response, minimizing infection risk, and providing necessary interventions to repair tissue damage. [24,25]

Cost and financial coverage are crucial considerations when determining the optimal strategy for individual patients. Limited publications address wound management of radiation ulcers in low-income environments. Moreover, several complex procedures may also not be feasible in settings of limited equipment. Similarly, cases 2 and 3 involved patients covered by Indonesia's Social Security Administrative Body (BPJS). While these cases may not represent the most advanced treatment options, this report demonstrates that simple wound treatment and standard reconstruction of the chest when applied appropriately, may still provide satisfactory results.

CONCLUSION

Managing radiation-induced tissue injuries, such as radiation dermatitis and osteoradionecrosis remains challenging due to conflicting evidence and limited high-quality studies. Preventive measures, such as optimizing radiotherapy planning and early use of topical agents and dressings, are crucial. Tailoring treatments to individual patients based on the severity of tissue damage and available resources is essential. While complex surgical interventions may be necessary in some cases, simpler wound treatments and standard reconstruction techniques can still yield satisfactory outcomes, particularly in low-resource settings. Collaborative, multidisciplinary approaches among healthcare professionals are essential for optimizing patient care and outcomes.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REKONSTRUKSI DAN ESTETIK

PROGNOSIS OF INHALATION INJURY MORTALITY RATE WITH REVISED BAUX SCORE AT DR SOETOMO GENERAL ACADEMIC HOSPITAL, SURABAYA, INDONESIA (2019-2021)

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ABSTRACT

Introduction: Burn trauma has quite a high mortality rate in Indonesia. One of the scoring systems that is straightforward to apply is the revised Baux score. However, there is no standardised scoring system that is currently in use in our institution. Therefore, the purpose is to determine the feasibility of using this scoring system in our population's features.
Methods: This research is a retrospective study with research design case control design using secondary data in the form of medical record data from patients with acute burn trauma that were admitted to Burn Unit of Dr. Soetomo General Academic Hospital in Surabaya between January 2019 and December 2021. All the data will be divided by their group and analysed with SPSS software.
Results: The study found significant relationships between several factors and mortality rates among burn patients. Age, total burn surface area percentage, presence of inhalation injury, and the revised Baux Score all showed significant correlations with mortality rate ($p < 0.005$). Specifically, among burn patients with inhalation injury, the correlation between mortality rate and revised Baux score remained significant ($p=0.002$).
Conclusions: The study revealed that age, the percentage of total burn surface area, and the presence of inhalation injury are significantly associated with mortality rate among burn patients. Additionally, the revised Baux Score was identified as a useful tool for predicting the prognosis of burn patients with inhalation injury. These findings emphasize the importance of these factors in assessing and managing outcomes for burn patients, particularly those with inhalation injury.

Highlights:

1. Fire is the most frequent cause of burns, while thermal contact is the least common.
2. Mortality rate with revised Baux score in burn patients with inhalation injury showed a significant relationship.

INTRODUCTION

Burn trauma is still an important issue, particularly in low- and middle-income countries. Although specific updated statistics for Indonesia's burn patient mortality rates in 2024 are not readily available, global trends suggest ongoing challenges in addressing burn injuries.[1] In 2012, Indonesia's burn patient mortality rate remained high, with rates of

27.6% in RSCM and 26.41% in Dr. Soetomo General Academic Hospital.[2] Based on World Health Organization (WHO) data in 2008, the mortality rate and crude death rate of Southeast Asian countries were the highest in the world compared to other countries. The mortality rate has risen to 184.000 per year, with a crude death rate of 11.6 per 100.000 inhabitants and a global death percentage of 59%.[1] In that situation, Indonesia, as a member of Southeast Asia, should devote more attention to burn injuries.[3,4] Clinicians should adopt a strategic approach based on demographic and specific characteristics to reduce death rates on Indonesian islands.

There are researches conducted to establish predictive values for burn mortality. The concept of stratification via a scoring system is widely established in clinical practice worldwide.[5] A good prognosis score should satisfy several criteria, including high accuracy, simplicity, and ease of application. Among the proposed scoring systems in the burns sector, one that is straightforward to apply is the revised Baux (abbreviated as rBaux) score.[6]

Professor Serge Baux developed a formula in 1961 to predict mortality in burn patients. The Baux score is calculated by adding the Total Burn Surface Area (TBSA) percentage and patient age to get a mortality score. Osler then proposed the revised Baux (rBaux) score in 2010, and it has since been evaluated and widely applied in developed countries. Osler adds inhalation injury since inhalation injury has been recognized as an important contributor to mortality after burn injury.[7] The rBaux score is calculated by adding together the percentage of Total Burn Surface Area (TBSA) and the patient's age. This score provides crucial predictive information for determining the prognosis of burn patients, where higher scores indicate a higher risk of mortality. One of the main advantages of the rBaux score is its simplicity in application. By considering only these two factors, the score can be calculated quickly and easily in various clinical settings. This simplicity makes it a valuable tool for clinicians in assessing burn patients and guiding treatment decisions based on prognostic factors.[1] Such a score has been investigated and applied in numerous centres worldwide, but no standardised scoring system is currently in use in our institution.

This study aimed to prove that the revised Baux score can determine the mortality rate prognosis of inhalation injury in burn trauma and determine the feasibility of using this scoring system in our population's features.

METHODS

This research is a retrospective case-control study conducted in February 2022, utilizing data collected from medical records of patients with acute burn trauma admitted to the Burn Unit of Dr. Soetomo General Academic Hospital in Surabaya. The study included all subjects admitted due to acute burns between January 2019 and December 2021. Exclusion criteria encompassed chronic burns, inhalation trauma accompanied by other trauma or comorbidities, missing data on variables, and loss to follow-up. A total of 214 patients admitted during the specified period were reviewed based on age, total burn surface area (TBSA), and presence of inhalation injury.

The data were categorized into groups and analyzed using SPSS software. The case group comprised patients with acute burn trauma treated at the Burn Unit of Dr. Soetomo Hospital in Surabaya during the study period. These individuals had specific conditions or diseases relevant to the research focus. The control group consisted of patients without a history of burn trauma and not subjects of burn trauma-related research. They served as a comparison group to assess the relationship between studied factors, such as age, total burned body surface area, and inhalation injury,

and clinical outcomes, including mortality among patients with burn trauma.

The researchers implemented a systematic and well-documented data collection process to ensure comprehensive acquisition of all necessary information for analysis. This data collection process allowed researchers to identify relevant patterns and trends regarding the studied risk factors.

Subsequently, the collected data underwent statistical analysis using software like SPSS to uncover patterns, relationships, and trends associated with the studied risk factors. The analysis was retrospective, utilizing historical data from patients' medical records to explore the relationships between specific risk factors, such as age, burned body surface area, and inhalation injury, with clinical outcomes, such as mortality among patients with burn trauma.

Inferential statistical techniques were applied to assess the statistical significance of the relationships between these variables. Depending on the research questions, Spearman correlation tests or logistic regression analysis may have been employed. The results of the analysis were thoroughly evaluated and interpreted to determine the existence and significance of relationships between the studied risk factors and clinical outcomes, particularly mortality among burn trauma patients. The result of this research will be presented with tables and graphics.

RESULTS

The dataset consists of 214 medical records from patients with acute burn injuries who were admitted to the Burn Unit of Dr. Soetomo General Academic Hospital Surabaya from January 2019 to December 2021.

Figure 1. Medical Record Data from Patients with Acute Burn Trauma Admitted to the Burn Unit of Dr. Soetomo General Academic Hospital Surabaya in the Period January 2019 - December 2021

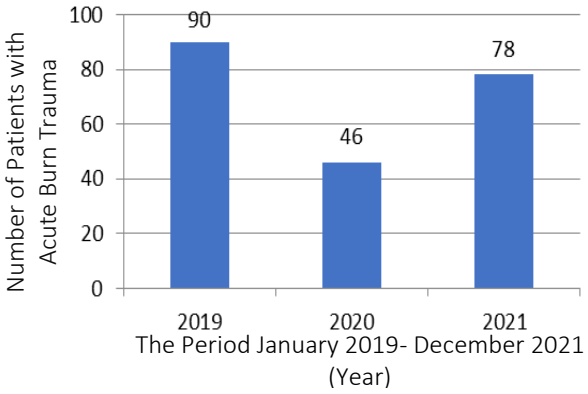


Table 1. Demographic Data of Burn Patients Dr. Soetomo General Academic Hospital Surabaya in the Period January 2019 - December 2021

Characteristics	n	%
Total Data	214	100
Gender		
Male	146	68.22
Female	68	31.78
Cause of burn		
Scald	61	28.5
Fire	113	52.8
Electric Injury	35	16.36
Chemical	4	1.87
Contact Thermal	1	0.47
Age		
0-10	47	21.96
11-20	25	11.68
21-30	28	13.08
31-40	37	17.29
41-50	42	19.63
51-60	19	8.88
61-70	12	5.61
71-80	4	1.87
81-90	0	0
91-100	0	0
Total Burn Surface Area (%)		
0-10	41	25.23
11-20	38	22.90
21-30	30	16.82
31-40	23	13.08
41-50	16	10.28
51-60	11	6.54
61-70	4	2.80
71-80	4	1.87
81-90	1	0.47

91-100	0	0
Inhalation Trauma Presence		
Yes	50	23.36
No	164	76.61

Comparison of sex from medical record data collected obtained 146 (68.22%) male and 68 (31.78%) female patients. This indicates that there were more male patients than female patients among those treated for burns during the study period. While the most common cause of burns is fire (52.8%), and the least common is thermal contact (0.47%). This suggests that fire-related incidents are the predominant cause of burns among the patients studied. The largest age group was 0-10 years, namely 47 patients (21.96%). This highlights the vulnerability of children to burn injuries. The group with the highest Total Burn Surface Area percentage was 0-10%, namely 41 patients (25.23%). This indicates that a significant proportion of patients had relatively minor burn injuries in terms of TBSA percentage. The number of inhalation injuries obtained from the data was 50 incidents (23.36%). This underscores the importance of considering inhalation injuries as a significant factor in burn cases, as they can have serious implications for patient outcomes and treatment strategies.

Table 2. Correlation Between Clinical Variables and Mortality Rate in Burn Patients

Clinical Variable	Correlation Coefficient	p-value
Age vs. Mortality Rate	0.213	0.002
TBSA vs. Mortality Rate	0.475	0.000
Inhalation vs. Mortality Rate	0.369	0.000

The table provides statistical outcomes from Spearman correlation tests conducted among various variables (age, Total Burn Surface Area (TBSA), Inhalation) and Mortality Rate in burn patients. Each correlation coefficient is accompanied by its respective p-value. Emphasizing statistically significant findings is crucial, typically those with p-values lower than a chosen significance level, commonly denoted as α (e.g., <0.05 or <0.001).

The Spearman correlation test results presented in Table 2 demonstrate significant associations between various variables and the Mortality Rate among burn trauma patients. Firstly, there exists a noteworthy positive correlation between age and Mortality Rate ($r=0.213$, $p=0.002$), indicating that older age is linked to increased mortality likelihood. Similarly, the Total Burn Surface Area (TBSA) exhibits a substantial positive correlation with Mortality Rate ($r = 0.475$, $p < 0.001$), suggesting that larger TBSA percentages are associated with higher mortality rates. Moreover, Inhalation injury shows a significant positive correlation with Mortality Rate ($r=0.369$, $p<0.001$), highlighting the heightened mortality risk among patients with inhalation injuries. These findings emphasize the critical role of age, TBSA, and Inhalation injury in predicting mortality and guiding clinical management strategies for burn trauma patients.

Table 3. Outcome Data of Burn Patients with Inhalation Trauma and without Inhalation Trauma at Dr. Soetomo General Academic Hospital Surabaya in the Period January 2019 - December 2021

Outcome	Inhalation Trauma	Without Inhalation Trauma
Alive	28	147
Dead	22	17

The data in the table presents a comparison of outcomes between patients with inhalation trauma and those without at Dr. Soetomo General Academic Hospital in Surabaya during the period from January

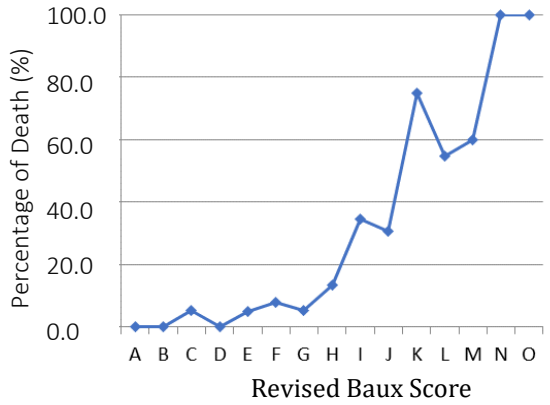
2019 to December 2021. The table indicates a significant difference in mortality rates between the two groups. Patients with inhalation trauma had a higher mortality rate (22 patients) compared to those without inhalation trauma (17 patients). However, the number of survivors among patients without inhalation trauma (147 patients) was substantially higher than among those with inhalation trauma (28 patients). These findings suggest an elevated risk of mortality associated with inhalation trauma.

The data above was analysed using SPSS to find the Odds Ratio and obtained an OR value of 6.79 ($p < 0.005$). This result follows previous research conducted by Osler, Glance and Hosmer (2010)[8], which said that inhalation trauma contributed to adding 17 years or 17% of the total burn surface area to the calculation of Baux Score.

Revised Baux Score data obtained from the calculation of age, Total Burn Surface Area percentage, and inhalation injury presence in all burn patients in this study then processed with actual mortality data that occurred, as shown in the following tables and figure bellow.

Table 4. Revised Baux Score Data with Actual Mortality of Burn Patients at Dr. Soetomo General Academic Hospital Surabaya in the Period January 2019 - December 2021

R-Baux Score	Alive		Dead	
	n	%	n	%
0-10	11	100.0	0	0.0
11- 20	17	100.0	0	0.0
21-30	18	94.7	1	5.3
31-40	20	100.0	0	0.0
41-50	20	95.2	1	4.8
51-60	23	92.0	2	8.0
61-70	18	94.7	1	5.3
71-80	13	86.7	2	13.3
81-90	17	65.4	9	34.6
91-100	9	69.2	4	30.8
101-110	2	25.0	6	75.0
111-120	5	45.5	6	54.5
121-130	2	40.0	3	60.0
131-140	0	0.0	2	100.0
>140	0	0.0	2	100.0



A : 0-10 F : 51-60 K : 101-110
B : 11- 20 G : 61-70 L : 111-120
C : 21-30 H : 71-80 M : 121-130
D : 31-40 I : 81-90 N : 131-140
E : 41-50 J : 91-100 O : >140

Figure 2. Plotting Percentage of Death with Revised Baux Score in Burn Patients

The data above found that the increase in the revised Baux Score value was in line with the actual mortality rate of burn patients and vice versa. In the lower Baux score categories (0-30), the mortality rate is relatively low or even non-existent. However, in higher ranges of the Revised Baux Score, especially above 80, there is a significant increase in the percentage of patients who die. For instance, in the range of 81-90, only 65.4% of patients survive, while 34.6% die. In the range of 131-140 and above 140, all patients succumb to mortality.

In this study, researchers also conduct Spearman correlation test to prove the magnitude of the relationship between the revised Baux Score and survival outcome of burn patients both with inhalation trauma and without inhalation trauma, with the following results shows a correlation coefficient of 0.495, which indicates a sufficient relationship between the revised Baux Score and the survival outcome of burn patients. The research also obtained a

significance value of 0.000, indicating a correlation between the Revised Baux Score and the mortality rate of burn patients.

Table 5. Revised Baux Score Data with Actual Mortality of Burn Patients with Inhalation Injury at Dr. Soetomo General Academic Hospital Surabaya in the Period January 2019 - December 2021

R-Baux Score	Alive		Dead	
	n	%	n	%
0-10	0	0.0	0	0.0
11- 20	0	0.0	0	0.0
21-30	0	0.0	1	100.0
31-40	0	0.0	0	0.0
41-50	1	100.0	0	0.0
51-60	2	100.0	0	0.0
61-70	5	100.0	0	0.0
71-80	1	100.0	0	0.0
81-90	5	62.5	3	37.5
91-100	5	71.4	2	28.6
101-110	2	33.3	4	66.7
111-120	5	50.0	5	50.0
121-130	2	40.0	3	60.0
131-140	0	0.0	2	100.0
>140	0	0.0	2	100.0

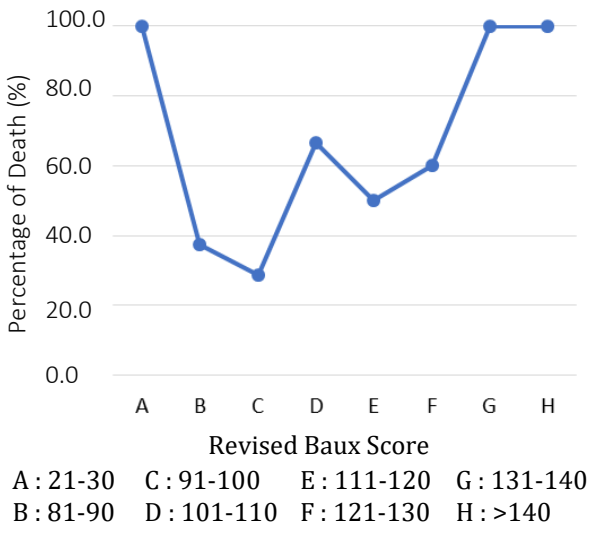


Figure 3. Plotting Percentage of Death with Revised Baux Score in Burn Patients with Inhalation Injury

Table 5 and Figure 3 found that the increase in the revised Baux Score value of burn patients with inhalation injury was in line with the actual mortality rate and vice versa.

In this study, researchers also conduct Spearman correlation test to prove the magnitude of the relationship between the revised Baux Score and survival outcome of burn patients with inhalation injury, with the following results shows a correlation coefficient of 0.423, which indicates a sufficient relationship between the revised Baux Score and the survival outcome of burn patients with inhalation injury. The research also obtained a significance value of 0.002, indicating a correlation between the Revised Baux Score of burn patients with inhalation injury and the mortality rate.

DISCUSSION

Burn injuries pose a significant challenge, particularly in Indonesia, a developing country in Southeast Asia, where the mortality rate from burns is increasing and has reached 27.6%.[3] The role of healthcare professionals in effective burn management is crucial. One strategy to enhance treatment outcomes involves using predictive models to evaluate mortality rates associated with burn injuries. Scoring systems for categorizing burn severity have become widely adopted in many countries. Among these systems, the revised Baux score (rBaux) stands out as a promising tool due to its simplicity and ease of use.[9,10]

The revised Baux score (rBaux) is a scoring system used in the assessment of burn injuries to predict mortality risk. It is an adaptation of the original Baux score, which was developed to estimate the likelihood of death in burn patients based on various clinical parameters. The rBaux score incorporates factors such as age, percentage of total body surface area (TBSA) burned, and inhalation injury to calculate a numerical score. This scoring system enables clinicians to categorize patients into different risk groups and make informed treatment decisions accordingly.

Healthcare professionals use the rBaux score to guide resource allocation and prioritize care, particularly in urgent situations requiring immediate triage. By accurately evaluating burn injury severity and forecasting patient outcomes, the rBaux score contributes to enhanced patient management and improved clinical results.[7,10-12]

In this study, an analysis was conducted to examine the relationship between age, total burn surface area percentage, inhalation injury presence, and the mortality rate among burn patients. These three variables significantly impact the mortality rate percentages observed in burn patients as determined by the revised Baux Score.

The Spearman correlation analysis between age and mortality rate revealed a statistically significant but weak relationship (p=0.002), suggesting that patients at extreme ages face a higher risk of mortality. These findings align with prior research, where older age (p=0.004) remained a significant risk factor for burn mortality after accounting for other variables. This increased risk in older individuals is attributed to a higher prevalence of pre-existing medical conditions, compromised immune responses against post-burn infections, and skin thinning leading to more severe burn injuries.[13]

According to previous studies, advancing age was a notable risk factor for seniors and adults but not for children (p=0.355).[14] In contrast, children's mortality rates decrease with age, likely due to the development of organs and immune systems.

The Spearman correlation test between total burn surface area percentage and mortality rate showed a significant relationship (p=0.000). This result shows that the wider the % total burn surface area, the higher the risk of mortality. These results follow previous research, namely that an increase in the percent burn area increases the risk of mortality (p<0.001) associated with wound infection, sepsis, and organ failure.[15]

The Spearman correlation test between inhalation injury presence and mortality rate showed a significant relationship (p=0.000). This result indicates that inhalation injury can increase the risk of mortality. This finding is also reinforced by data analysis using the Odd Ratio, where there is a 6-fold increase in mortality in burn patients with inhalation injuries. Additionally, one study demonstrated that inhalation trauma contributes significantly to the calculation of the Baux Score, potentially adding 17 years or 17% of the total burn surface area.[16] Another study highlighted that combining cutaneous burns with inhalation injury leads to increased fluid requirements for resuscitation, higher incidence of pulmonary complications, and elevated mortality rates.[17]

After establishing the significant relationship between the three variables in the revised Baux Score and the mortality rate of burn patients, the study proceeded to analyze the correlation between the revised Baux Score obtained from patient data and the actual mortality rate. The researchers plotted the percentage of survival and mortality against the revised Baux Score and conducted a Spearman correlation test. The findings revealed that higher values of the revised Baux Score corresponded to higher percentages of mortality. The Spearman correlation test confirmed a significant relationship between the revised Baux Score and mortality rate (p=0.000), indicating that higher revised Baux Scores were associated with increased mortality rates. Furthermore, the researchers specifically analyzed the correlation between the revised Baux Score and mortality rate in burn patients with inhalation trauma, uncovering a significant relationship (p=0.002). This suggests that inhalation trauma in burn patients can elevate

mortality risk. The study's data also highlighted that burn patients with inhalation trauma, coupled with extensive burns (mean TBSA 40.84%) and advanced age (mean age 40.2 years), exhibited a high mortality rate.

The results of this study align with previous research conducted at Dr. M. Djamil Padang Hospital, where logistic regression analysis demonstrated an interrelation between age, TBSA, and inhalation trauma in predicting mortality using the revised Baux score ($p < 0.001$).[17] Similarly, research at Dr. Cipto Mangunkusumo General Hospital indicated significant predictive discrimination of the r-Baux score for burn patient mortality ($p < 0.001$).[18] Additionally, a study at Chelsea and Westminster Hospital also found a significant relationship between the revised Baux Score and mortality rate ($p < 0.001$).[19]

These findings support the use of the revised Baux score in predicting prognosis for burn patients with inhalation injuries. Implementing effective prognostic scoring systems like the rBaux score can aid clinicians in accurately assessing burn injury severity and predicting patient outcomes. By integrating these tools into clinical practice, healthcare providers can make informed decisions and allocate resources more efficiently, potentially improving survival rates and enhancing burn trauma management in Indonesia.

The limitation of the study is that it cannot calculate the mortality rate of burn patients who do not meet the criteria for hospitalization, even though even the smallest burn carries a risk of morbidity and mortality.[20] However, the strengths and novelty of this study lie in its comprehensive data collection from medical records of burn trauma patients admitted to the Burn Unit of Dr. Soetomo General Academic Hospital Surabaya, spanning from January 2019 to December 2021. This extensive data collection enhances the robustness of the study's findings. The research considers various factors such as age, Total Burn Surface Area (TBSA), and inhalation injury in assessing their correlation with mortality rates among burn trauma patients. This comprehensive approach allows for a thorough examination of potential risk factors. The study employs Spearman correlation tests to analyze the relationship between different variables (age, TBSA, inhalation) and mortality rate, ensuring rigorous data analysis. The findings of the study have direct implications for clinical practice, particularly in burn management. By identifying significant correlations between age, TBSA, inhalation, and mortality rate, clinicians can better understand and manage burn trauma cases, potentially improving patient outcomes. Additionally, the study contributes to the existing body of knowledge on burn trauma management by specifically examining the predictive value of the revised Baux score in the study population. This novel aspect of the research adds valuable insights to the field of burn care.

CONCLUSION

The revised Baux Score is effective for predicting mortality prognosis in burn trauma cases involving inhalation injury. Age, percentage of Total Burn Surface Area, and the presence of inhalation injury significantly impact mortality prognosis in burn trauma. To enhance understanding of the revised Baux Score's predictive accuracy for mortality in burn patients, future studies could compare it with other prognostic scoring systems like BOBI and ABSI.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this study.

FUNDING DISCLOSURE

The authors declare that there is no financial interest in this study.

AUTHOR CONTRIBUTION

DHS contributed to the conception and study design, collection and assembly of data, analysis and interpretation of the data, RM contributed to the methodology, drafting of the article and project administration, ASB and DMI contributed to the critical revision of the article for important intellectual content. All authors participated in the final proofreading.

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THE OCCURRENCE OF CONTRACTURE AND THE SEVERITY OF BURN INJURIES AMONG BURN PATIENTS TREATED AT DR. SOETOMO GENERAL ACADEMIC HOSPITAL, SURABAYA, INDONESIA (2020-2022)

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ABSTRACT

Introduction: Burn injuries are a worldwide issue and can happen for many reasons, often causing skin damage that leads to deformities and movement difficulties. Many burn patients, up to 50%, experience contractures, which limit movement in areas such as the shoulders, wrists, and torso. Proper management through medicine, surgery, and therapy is crucial for helping these patients. Research at Dr. Soetomo General Academic Hospital is focused on studying the frequency of contractures after burn injuries to improve treatment and prevention methods.
Methods: The research used descriptive analytics and gathered data from the Burn Unit at Gedung Bedah Pusat Terpadu (GBPT) and the Plastic Surgery Polyclinic at Dr. Soetomo General Academic Hospital in Surabaya. The study examined 40 eligible patients and assessed variables including burn severity, affected body area, and hospitalization duration.
Results: The results showed that the average age of patients was 26.30 years, with 70% of them being male. Only 5% of patients had other health problems, mainly related to hormones. Most burns were caused by fire (37.5%), and many were second-degree burns (42.5%). The percentage of the body affected by burns varied by age: children had around 9.86%, adolescents had around 15.96%, and adults had around 5.25%. Most injuries were on the left arm (67.5%), and many patients stayed in the hospital for a long time (67.5%).
Conclusion: All patients developed contractures following burns, irrespective of burn severity. There was a correlation between burn size and severity, except among older patients. Additionally, a notable association was observed between contracture occurrence and prolonged hospitalization.

Highlights:

1. A robust association was observed between total body surface area (TBSA) and burn injuries, except in the case of elderly individuals.
2. The duration of hospitalization is significantly associated with the occurrence of contracture.

INTRODUCTION

Burn injury is a prevalent issue worldwide and a significant cause of patient complications. According to the World Health Organization (WHO)[1], a lot of countries struggle to provide adequate care for individuals affected by burn injuries due to their widespread occurrence. Annually, approximately 180,000 deaths are attributed to burns, with a higher incidence observed in nations with lower to moderate economic status. In Southeast Asia, there is an estimated occurrence of 1.3 burn patients per 100,000 population.[1-3]

In Indonesia, approximately 195,000 deaths occur each year due to burn injuries, and this number is rising due to population growth and industrial development. The Burn Unit at Dr. Soetomo General Academic Hospital experiences an increasing number of cases annually, with a higher mortality rate.[4-7] Specifically, the Burn Centre at Cipto Mangunkusumo General Hospital receives over 130 patients annually from various parts of the country.[8] Perdanakusuma et al. (2019) the mortality rate among burn patients at Dr. Soetomo General Hospital in Surabaya, Indonesia, was 14.1% between 2007 and 2011.[9]

Burn injuries can result from various factors, including electrical shock, fire, cold, and friction, as discussed in this study. Based on data collected from the Burn Unit of Dr. Soetomo General Academic Hospital in 2017-2020, the leading causes of burns in sequential order were electricity (19%), fire (56%), and other (25%).[2,10] These injuries damage body tissues, potentially leading to deformities and loss of function, often resulting in complications such as contractures, which are a significant concern. Research indicates that contractures occur in 18 to 50 percent of burn patients, affecting both adults (up to 42%) and pediatric cases (up to 23%). These contractures can severely limit patients' range of motion in areas like the shoulder, wrist, and dorsiflexion, impacting their quality of life. Effective management of burn injuries involves pharmacological, surgical, and therapeutic interventions to improve patients' health and well-being.[11]

In response to the challenges posed by burn injuries, there has been a growing emphasis on research and public health initiatives aimed at prevention, early intervention, and improved treatment outcomes. Collaborative efforts between healthcare professionals, researchers, policymakers, and community organizations have led to the development of innovative strategies for burn prevention, including public education campaigns, improved building safety regulations, and advancements in burn care technologies. Additionally, interdisciplinary approaches to burn care, such as comprehensive rehabilitation programs and psychosocial support services, are being implemented to address the complex needs of burn survivors throughout their recovery journey.

Burn injuries often result in complications, with contractures being a prevalent concern, especially in relation to the injury's severity and complexity. Prior studies has indicated a significant correlation between the seriousness of burn contractures in adults and the size of the injury's surface area. The ongoing research at Dr. Soetomo General Academic Hospital aims to investigate the correlation between contracture occurrence and burn injuries, addressing gaps in current knowledge and contributing to the development of enhanced treatment and prevention strategies for patients.

METHODS

The study used a descriptive analytics approach to gather information from burn patients treated at Gedung Bedah Pusat Terpadu (GBPT) and the Plastic Surgery Polyclinic at Dr. Soetomo General Academic Hospital in Surabaya, Indonesia. Data was collected from medical records spanning from January 2020 to July 2022, covering

both burn injuries and subsequent contractures. Analysis of the data was conducted using IBM SPSS Software. The sample comprised individuals with burn injuries treated at GBPT and those with post-burn contractures treated at the Plastic Surgery Polyclinic of Dr. Soetomo General Academic Hospital during the specified time period. Approval for accessing patient records was obtained from the Health Research Ethics Committee of Dr. Soetomo General Academic Hospital in Surabaya, Indonesia. (No.1199/LOE/301.4.2 /I/2023).

The study concluded with a total of 40 patients included. The selection criteria encompassed individuals with burn injuries, those who developed post-burn contractures, and those hospitalized for burn injuries at Dr. Soetomo General Academic Hospital between January 2020 to July 2022. The gathered data underwent processing using IBM SPSS Software and was presented through graphs, tables, and analytical discussions. Data analysis involved descriptive tests and correlation tests.

RESULTS

Table 1 below presents patient demographics, including information on the distribution of ages in years, gender, and the medical history and comorbidities of patients.

Table 1. Patient Demographics

Patient Demographics (n = 40)	**n**	**%**
Age (years)		
Mean ± SD	26.30 ± 20.21	-
Median	26.5	-
0 – 9 years	14	35
10 – 59 years	24	60
> 60 years	2	5
Sex		
Male	28	70
Female	12	30

From a total of 40 cases analyzed in this study, the average age was 26.30 years with a standard deviation of 20.21, and a median of 26.5 years. The ages ranged from 1 to 71 years old. The most common age group was between 10 to 59 years old, accounting for 24 cases (60%) of the total. Conversely, the least common age group was >60 years old, with only 2 patients (5%). Additionally, the majority of cases were male, comprising 28 patients (70%), while female patients accounted for 12 cases (30%).

Table 2. Patient's Past Medical History and Comorbidities

Patient's Past Medical History and Comorbidities (n = 40)	**n**	**%**
Endocrine		
Disorders of plasma protein metabolism	2	5
Diabetes mellitus	1	2.5
Anaemia	1	2.5
Hypokalaemia	1	2.5
Neurological disorders		
Developmental disorder of speech and language	2	5
Adjustment disorders	1	2.5
Cardiovascular		
Essential hypertension	2	5
Digestive		
Hepatitis B	2	5
Musculoskeletal		
Talipes equinovarus	1	2.5
Stiffness of joint	1	2.5
Integumentary system		
Open wound	1	2.5
Keloid scar	1	2.5
Respiratory		
COVID-19	1	2.5
Others		
Non-Hodgkin lymphoma	1	2.5
Ca mammae dextra	1	2.5
Undernutrition	1	2.5

As depicted in Table 2, patient medical histories varied, with endocrine disorders being the most prevalent comorbidities, including plasma protein metabolism

disorders (5%), diabetes mellitus, anaemia, and hypokalaemia (2.5% each). Neurological disorders, such as developmental and adjustment disorders, were the second most common (5% and 2.5%, respectively). Uncategorized comorbidities like non-Hodgkin lymphoma, breast cancer, and undernutrition each comprised 2.5% of cases.

Table 3. Clinical Characteristics of Burn

Clinical Characteristics of Burn (n = 40)	**n**	**%**
Causes of Burn		
Fire	15	37.5
Electrical burn	14	35
Boiling water	6	15
Boiling oil	4	10
Vehicle exhaust	1	2.5
Degree of Burn		
First degree	8	20
Second degree	17	42.5
Third degree	15	37.5
TBSA in Children (0-9 years)		
Mean	9.86 ± 2.26	-
Median	7	-
< 5%	6	15
5 – 10%	2	5
> 10%	6	15
TBSA in Adolescence and Adults (10-59 years)		
Mean	15.96 ± 3.19	-
Median	10	-
< 10%	11	27.5
10 – 20%	6	15
> 20%	7	17.5
TBSA in Elderly (>60 years)		
Mean	5.25 ± 4.75	-
Median	5.25	-
< 5%	1	2.5
5 – 10%	1	2.5
> 10%	0	0
Location of Burn Injury		
Left superior extremity	27	67.5
Right superior extremity	26	65
Anterior trunk	9	22.5
Posterior trunk	3	7.5
Head and neck	15	37.5
Left inferior extremity	14	35
Right inferior extremity	17	42.5

Table 3 highlights fire as the primary cause of burn injuries (37.5%), followed by electrical burns (35%) and boiling water (15%). Burn degrees, showed second-degree burns as most prevalent (42.5%). Total body surface area (TBSA) classifications, following Singer et al. (2008)[6] criteria, revealed varying means across age groups. Children had a mean TBSA of 9.86 ± 2.26%, with prevalent cases having TBSA <5% and >10% (15% each). Adolescents and adults showed a mean TBSA of 15.96 ± 3.19%, with less than 10% TBSA being most prevalent (27.5%). The elderly exhibited a mean TBSA of 5.25 ± 4.75%, with cases falling below 5% and between 5-10% (2.5% each). Burn injury locations varied, with the superior extremities being most common (67.5% left, 65% right), followed by inferior extremities (35% left, 42.5% right), and the posterior trunk being least common (7.5%).

Table 4. Outcome of Burn Patients

Outcome of Burn Patients	**n**	**%**
Length of hospitalisation		
Mean	8.85 ± 0.81	-
Median	8	-
Short (<4 days)	6	15
Intermediate (4-6 days)	7	17.5
Prolonged (>6 days)	27	67.5
Patient outcomes		
Hospital discharge due to improved conditions	39	97.5
Deceased	1	2.5
Complications		

Integumentary disorders	10	25
Shock	3	7.5
Inhalation trauma	1	2.5
Compartment syndrome	1	2.5
Gastrointestinal tract disorder	1	2.5

Table 4 presents burn injury patient outcomes in terms of hospital stays. The mean hospital stay was 8.85 ± 0.81 days, with 67.5% experiencing prolonged stays, 17.5% intermediate stays, and 12.5% short stays. Patient outcomes included 2.5% deaths and various complications. Integumentary disorders were most prevalent (25%), followed by shock (7.5%), inhalation trauma, compartment syndrome, and gastrointestinal tract disorders (each 2.5%). The study offers valuable insights into burn injury patient outcomes and associated complications.

Table 5. Characteristics of Contracture

Clinical Characteristics of Contracture (n = 40)		**n**	**%**
Occurrence of contracture			
Yes		40	100
Location of contracture			
Left superior extremity	Shoulder	2	5
	Axilla	1	2.5
	Elbow	2	5
	Wrist	8	20
	Fingers	13	32.5
	Unspecified	1	2.5
Right superior extremity	Shoulder	3	7.5
	Axilla	2	5
	Elbow	5	12.5
	Wrist	8	20
	Fingers	10	25
	Unspecified	2	5
Anterior trunk	Unspecified	4	10
Posterior trunk	Unspecified	2	5
Head and neck	Face	4	10
	Neck	5	12.5
Left inferior extremity	Knee	6	15
	Ankle	2	4.5
	Toes	4	10
Right inferior extremity	Hip	1	2.5
	Knee	5	12.5
	Ankle	2	5
	Toes	6	15
	Unspecified	1	2.5

As detailed in Table 5, all patients in this study experienced contracture, with the right superior extremity being the most prevalent location (75%). Contractures in wrists and fingers (both sides) accounted for 20% and 32.5% in the left side and 20% and 25% in the right side, respectively. Inferior extremities had 30% on the left side and 37.5% on the right side, with the knee (12.5%) and toes (15%) as the most common locations. The study employed the one-sample T-test in IBM SPSS to analyze the occurrence of contracture and degree of burn injury, with results presented in Table 6.

Table 6. Correlation between Occurrence of Contracture with the Degree of Burn Injury

	Degree of Burn Injury			**p-value**
	First	**Second**	**Third**	
Contracture	8	16	16	0.000

Data in the table indicates that, irrespective of burn severity, most patients experienced contractures. Occurrence in second and third-degree burns was 16 cases each, while first-degree burns had 8 cases. Statistical analysis revealed significant correlation (p-value = 0.000, below the cut off of 0.05).

Table 7 reveals 14 cases of contracture in children, 24 in adolescents/adults, and 2 in the elderly. Statistical analysis indicates significant correlation in children and adults (p-values 0.001 and 0.000 respectively, below 0.05), but not in the elderly group.

Table 7. Correlation between Occurrence of Contracture with the TBSA of Burn Injury

	TBSA		
	Children	**Adolescence and Adults**	**Elderly**
Contra-cture	14	24	2
p-value	0.001	0.000	0.468

The table 8 indicates 6 cases of contracture in patients with short hospital stays, 7 in intermediate stays, and 27 in prolonged stays. Statistical analysis reveals significant correlations (The p-values are 0.0025 for short stays and 0.000 for both intermediate and prolonged stays, all of which are below 0.05).

Table 8. Correlation between Occurrence of Contracture with LOS

	LOS		
	Short	**Intermediate**	**Prolonged**
Contra-cture	6	7	27
p-value	0.025	0.000	0.000

DISCUSSION

The average age in the study was 26.30 ± 20.21, ranging from 1 to 71 years, with the majority of participants falling between the ages of 10 and 59 (60%). Male patients outnumbered female patients, accounting for 70% and 30% respectively, consistent with findings from Australia and New Zealand, where males comprised 72.4% of burn injuries compared to females at 27.6%.[12,13] It was observed that until the age of 84, men had a higher proportion of burn injuries compared to women; however, after that age, both genders had equal proportions. Another study also discovered a higher percentage of male patients (56%) compared to female patients (44.8%).[14] The explanation for the gender discrepancy in the adult population varies with the mechanism of burn injury. Men are generally more involved in high-risk occupations, leading to a higher prevalence of burn injury caused by petrol fire, interpersonal violence, fire burns, hot liquid burns, and incidents involving alcohol or other substances. On the other hand, women have a higher prevalence of burn injuries caused by kerosene stove explosions and self-inflicted burns, which may be attributed to their tendency to be more involved in household activities and chores.[15]

Most patients in the study had a history of endocrine diseases (12.5%), followed by neurological disorders (7.5%) and cardiovascular illnesses (5%). Previous research identified diabetes and congestive heart failure as the most common comorbidities among burn patients. Over 57% of elderly patients had additional health conditions.[16] In this study, the presence of comorbidities did not affect patient outcomes; most patients were discharged upon showing signs of improvement, and only one death was recorded, although this correlation was not statistically tested. Additionally, no worsening of conditions related to comorbidities was documented during hospitalization, further supporting this statement.

In this study, fire combustion (37.5%) was the leading cause of burns, followed by electrical burns (35%) and scald burns (15%). This aligns with past research showing that flame burns were most common among young adults aged 18 to 64, while scald injuries became more prevalent with age. Many burns in the elderly occur during cooking or bathing, consistent with this mode of injury.[13] Mechanism of injury are also influenced by the geographical factors. According to one meta-analysis, gas and kerosene are the most common fuels in Iranian homes and workplaces, resulting in burns primarily from fire combustion. In contrast, scalds are the most frequent cause of burns in nations like Singapore and Denmark, although the underlying causes remain unknown.[14] Another study found

scald burns to be the leading cause (39%), followed by flame burns (33.6%) and electrical burns (26.6%). Diverse causes may stem from cultural and population variations. Children often experience steam burns, while adults face higher risks of electrical and flame burns, often associated with hazardous occupations. Scald injuries in children result from unsupervised play near hot liquids in kitchens.[17]

Second-degree burn was found the most predominant in this study, compromising of 16 (40%) cases, followed by third-degree burn injuries, which comprised 15 cases (37.5%), and first-degree burn injuries, comprising 8 (20%) cases. This finding is consistent with that of Alajmi et al. (2021), who discovered that the prevalence of second-degree burns was highest (71.1%), followed by third-degree burns (16.1%), and first-degree burns (12.8%).[18] However, no plausible explanation for the varying prevalence of the degree of burn injury has been found. Research suggests that the mechanism of injury strongly influences the degree of burn injury. Electrical burns, for example, are mostly full-thickness because nerves, blood vessels, and muscles conduct electricity and are easily damaged. Age groups also plays contributing factor in this phenomenon. The pediatric and elderly populations are prone to burn injuries due to their thinner skin depth, which might contribute to the higher prevalence of second-degree burns. Adults and the elderly often endured full-thickness burns while younger age groups commonly experience superficial second-degree burns. The type of burn, influenced by flame and electrical sources, contrasts with scalding, which causes first and second-degree burns.[17]

In children, the mean Total Body Surface Area (TBSA) was 9.86 ± 2.26%. Most cases comprised TBSA less than 5% or more than 10%, with 6 (15%) cases each. In the adolescence and adult group, the mean TBSA was 15.96 ± 3.19%, with burn injuries compromising less than 10% of the body surface area being the most prevalent, consisting of 11 (27.5%) cases. Meanwhile, in the elderly group, the mean TBSA was 5.25 ± 4.75%. Each case (2.5%) of 1 patient was found to suffer from less than 5% of total body surface injury and 5-10% of total body surface injury, respectively. This finding was similar to study conducted by Mulatu et al. (2022), where the mean TBSA in adults was 15.49%, ranging from1% to 64%. Similar to degree of burn injury, TBSA is also highly influenced by mechanism of injury. In flame burns, higher TBSAs (>20%) are more common than in other burn types. This could be attributed to the type of offending agent used and the duration the victim was in contact with it.[10] Patients with flame and explosion injuries had a higher average TBSA compared to those with scalding burns.[19]

The location of burn injury varies widely in this study. The most prevalent locations ware the left and right superior extremities, followed by left and right inferior extremities. The least prevalent location in this study was the posterior trunk. This finding was similar to previous study where it was found that most patients sustained burns on the upper (62.2%) and lower limbs (49.4%), followed by the head (46.7%) and chest (20%)[18]. Differences in sample size may account for variations in burn injury prevalence across studies. Despite percentage variations, most studies find extremities as a commonly affected site due to their susceptibility to manipulation and exposure to boiling liquids, particularly affecting lower extremities.[20]

Hospital stay length (LOS) poses a substantial financial burden on patients, families, providers, and hospitals. Numerous studies highlight age, burn size, and inhalation injury as predictors of mortality and extended LOS post-acute burn injury.[21] The average LOS in our study was found to be 8.85 ± 0.81 days, with the majority of patients experiencing prolonged stays, lasting more than 6 days. The length of stay is strongly correlated with the degree

of burn injury. A study indicated that most patients hospitalized for more than 14 days suffered from more than 20% Total Body Surface Area (TBSA) burns.[22] Age and comorbidities also impact LOS. The proportion of patients with comorbid conditions increases with age, and the presence of comorbidities, particularly in the older adult population, may contribute to increased hospital LOS.[23]

Patient outcomes were recorded in terms of discharge due to improved conditions and any occurrences of death. In this study, only one case of death was documented, involving a 19 year old patient. Although no comorbidity was documented, the patient suffered from extensive third-degree burn injuries covering 55% of Total Body Surface Area (TBSA). During hospitalization, the patient developed multiple complications including septicemia, acute respiratory distress syndrome, gastrointestinal hemorrhage, and open wounds to other parts of the head, among others. This finding is consistent with previous research, which indicated that the most severe conditions leading to death included septic shock, acute respiratory distress, and the presence of multiple traumas.[8]

Thirty out of 40 patients in our study developed complications. The most prevalent complication was integumentary disorders, followed by shock. Other complications included inhalation trauma, compartment syndrome, and gastrointestinal tract disorders. The frequency of patients developing more than three complications simultaneously during hospitalization was observed to be highest in the children age group, those sustaining burn injuries from fire combustion, and those with more than 20% TBSA. Mechanism of injury and TBSA may be related to the severity and extent of damage caused, thus influencing the development of complications. In children, intensive care may be more complex, and hemodynamic instability may contribute to a higher risk of complications.

Complications in burn cases exhibited significant variability among studies. One study identified burn wound site infection and sepsis as prevalent early in-hospital issues, with subsequent occurrences of anemia, hospital-acquired pneumonia, respiratory failure, and electrolyte imbalance. Meanwhile, amputation of extremities and hypertrophic scars were common long-term complications.[17]

All patients in our study developed contracture, regardless of the degree of burn. This finding is consistent with previous research, which identified contracture as one of the most common long-term complications.[17] There are numerous reasons for the relatively high incidence of contracture, including larger TBSA and skin grafting, which statistically increase the risk of developing contractures.[24] The study found that contractures were most common in the wrists and fingers of both left and right superior extremities. Contractures were also observed in the knees on the left side and toes on the right side of the inferior extremities. This aligns with research highlighting post-burn contractures as frequently occurring in hands, especially the fingers.[25] Hand involvement in burns explains the common occurrence of contractures in this study, which differs from other research findings.[24] Differences in contracture location may result from various factors, with the site of burn injury being a significant factor. Male sex, 40% TBSA burns, and surgical burn treatment are all risk factors for contracture development.[26]

A study identified a correlation between burn severity and hand contractures. First and superficial second-degree burns typically heal within two weeks, demonstrating good function and appearance. Deeper burns require a longer healing time and can lead to the formation of scar tissue. Utilizing skin grafts or

substitutes in acute management accelerates healing, promotes early motion, and reduces the development of contractures. The location of the burn also influences contracture formation, with the dorsal skin and extensor mechanism being more prone to contractures than the palmar side due to their unique properties.[27] This finding is consistent with our study, which observed that the majority of contractures occurred in the second- and third-degree burn group.

In our study, contractures were prevalent irrespective of the severity of burns, with 16 instances observed in both second and third-degree burns, and 8 cases in first-degree burns. Statistical analysis confirmed the significance (p-value 0.000) for all burn degrees, consistent with prior findings associating burn depth with contracture severity. Full-thickness burns are more likely to result in severe contractures, emphasising the correlation between burn depth and contracture outcomes.[28] Significant and full-thickness burns pose a higher risk of initiating joint mobility deficiency and disability in ambulation, fine motor duties, as well as daily functional activities.[29]

Myofibroblasts play a vital role in scar contraction by releasing TGF-1 and other cytokines, along with various cell types such as inflammatory cells, fibroblasts, endothelial cells, and epithelial cells. This secretion forms a positive feedback loop, maintaining myofibroblast activation.[30] The depth of burn injuries, influencing myofibroblast generation, exhibiting a potential linear relationship. Microenvironments, such as mechanical tension and integrin interactions, contribute to scar contracture. Extensive burns may disrupt healing, leading to excessive myofibroblasts and heightened contracture severity.[31] Post-burn contractures in children and young adults often involve early inflammation, particularly in mobile areas like the thorax and upper limb, lasting for months. This phenomenon may transiently occur during the initial two years and subsequently resolve.[32]

In our study, contracture occurrence was observed in 14 cases in children, 24 cases in adolescents and adults, and 2 cases in the elderly. Statistical analysis revealed a significant relationship in the children as well as the adolescent and adult population, but no significant relationship was found in the elderly group. Studies indicate that a higher Total Body Surface Area (TBSA) increases the likelihood of crossing multiple joints, posing a high risk of contractures.[29] Another study states that TBSA grafting and TBSA burn are independent predictors of contracture occurrence and number. Various injury-related factors, including burn depth, extent, cause, and location, are traditionally associated with contracture development. Larger burns often necessitate multiple surgeries, requiring postoperative immobilization for proper healing. Prolonged ICU stays, common in extensive burn cases, correlate with high contracture rates. The limited sample size in the elderly group might explain the observed insignificant correlation, highlighting the need for a more substantial sample size for thorough analysis.

In our study, contracture occurrence correlated significantly with hospital stay length: 6 cases in short stays, 7 in intermediate, and 27 in prolonged stays. This aligns with previous research highlighting hospitalisation duration as a contributing factor to contracture incidence.[29] In another study, 39% of non-burn-injured ICU patients who stayed longer than two weeks had contractures, with 34% of those being functionally limiting. Prolonged ICU stays (>14 days) may significantly contribute to contracture development.[24] Extended immobility, such as more than 2 weeks in a normal joint, results in fibrosis, synovial shortening, and reduced synoviocyte proliferation. Local factors like catheters and restraints, along with generalized immobility, contribute to multiple contractures.[33]

This study is reliable and comprehensive, with a diverse range of samples, from children to elderly, providing broad insights into burn injuries. Meticulous analysis of demographics and clinical characteristics, along with robust statistical analyses, strengthens scientific validity. The study's novelty lies in correlating contractures with patient characteristics, offering quantifiable insights. Focused on Dr. Soetomo General Academic Hospital, it addresses a specific gap in burn injury research. However, there are certain restrictions that affect generalizability, such as a small sample size, a retrospective design, and the absence of a control group. Future research with larger samples and comprehensive data can overcome these limitation.

This information gives a nuanced understanding of how age and gender play roles in the occurrence and causes of burn injuries, contributing to a comprehensive view of burn injury patterns in the studied population. Complications were noted in a significant number of patients, particularly in children, those injured by fire combustion, and those with higher TBSA, suggesting a link between the mechanism of injury, TBSA, and complication development. The novelty of the study lies in its comprehensive analysis of burn injuries across diverse age groups, providing nuanced insights into gender-based differences in mechanisms of injury. The study uniquely correlates burn types with age groups, emphasizing variations in injury mechanisms and outcomes. Additionally, it sheds light on the prevalence of endocrine diseases among burn patients, particularly in the elderly, contributing to the existing body of knowledge on comorbidities associated with burn injuries. The study's focus on correlating contractures with patient characteristics, including age, burn severity, and treatment methods, adds a distinctive dimension. The detailed exploration of complications and their variability among different patient groups provides valuable information. The inclusion of Total Body Surface Area (TBSA) analysis across age groups contributes to understanding burn severity patterns.

Furthermore, the study's emphasis on geographical factors influencing burn mechanisms, such as the prevalence of gas and kerosene in Iranian homes, adds a unique perspective. The study also addresses the correlation between hospital stay length and contracture occurrence, offering insights into the impact of prolonged immobility on patient outcomes.

CONCLUSION

All patients experienced post-burn contracture across all degrees. There is a positive correlation between Total Body Surface Area (TBSA) and burn injury, except in the elderly group. Moreover, an association has been observed between the incidence of contracture and the duration of hospital stay. Additionally, there is a correlation between the occurrence of contracture and TBSA in children, adolescents, and adult patients, but not in the elderly.

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CONFLICT OF INTEREST

The authors state that they have no conflicts of interest to disclose.

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None.

AUTHOR CONTRIBUTION

Designed the study and drafted the manuscript: GMQH and IDS. Collected data and performed background literature review: GMQH. Performed statistical analysis: GMQH. Supervised results and discussion: IDS, DMI, LS. The final version of

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REGENERATIVE MEDICINE IN BURN INJURY: A BIBLIOMETRIC ANALYSIS AND LITERATURE REVIEW

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ABSTRACT

Introduction: Burn injuries represent a significant global health concern, demanding effective management strategies to mitigate their impact. Regenerative medicine offers promising approaches to address burn injury management, utilizing innovative techniques to improve wound healing and tissue regeneration. This paper presents a comprehensive bibliometric analysis and literature review, highlighting trends, hotspots, and article profiles in the application of regenerative medicine for burn injury management, offering valuable insights for future research to enhance burn care.

Methods: A Scopus database search spanning from 2004 to 2024 was conducted using keywords related to regenerative medicine, burn injuries, and wound healing, yielding 602 relevant documents for analysis. Subsequent bibliometric analysis using VOSviewer and Biblioshiny identified key trends and contributors in the field.

Results: The results indicate an increase in research studies over the years, peaking in 2022, followed by a slight decline. Zhang Y emerged as the top researcher, with the United States leading in research output. Researchers primarily focused on four main areas: materials and techniques, injury management, cell-based therapies, and wound healing strategies. Emerging areas such as 3D printing, nanotechnology, and photothermal therapy are gaining interest for future research.

Conclusion: This study provides valuable insights into the evolving landscape of regenerative medicine for burn injury management. Zhang Y's significant contributions and the United States' leading role underscore the global effort in advancing research in this area. The exploration of new technologies like 3D printing and nanotechnology, alongside traditional approaches, signifies the dynamic nature of biomedical research in addressing burn injuries.

Highlights:

1. This research analyzes regenerative medicine trends for burn injuries, providing valuable insights into focal points and article characteristics, enhancing understanding of this critical healthcare issue.
2. This research analyzes trends in regenerative medicine for burn injuries, highlighting emerging areas like 3D printing, nanotechnology, and photothermal therapy as promising future research directions.

INTRODUCTION

Burn injuries pose a significant global health challenge and can be life-threatening.[1] It is caused by exposure to hot liquids, solids, flames, radiation, electricity, friction, or chemicals. Burns contribute significantly to injury, disability, and mortality, particularly in low-to-middle-income countries.[2] Extensive burn injuries have lasting physical effects, including persistent pain, scarring, inflammation, metabolic changes, contractures, amputations, and disfiguring scars.[3,4] These injuries are recognized not only as acute trauma but also as a chronic disease, impacting various body systems and leading to long-term consequences for mortality, metabolism, immune function, cardiovascular health, and susceptibility to infections and tumors.[5]

Regenerative medicine is a multidisciplinary field focused on repairing, replacing, or regenerating cells, tissues, or organs to restore impaired function caused by congenital defects, disease, trauma, or aging.[6] In the context of burn injuries, regenerative medicine plays a crucial role by offering innovative approaches for wound healing. Stem cells and their derivatives, such as exosomes and conditioned media, have shown promise in promoting burn wound repair through various signaling pathways.[7] The benefits of regenerative medicine for burn injuries include enhanced skin repair, reduced scar formation, improved immune response, and functional skin reconstruction. Overall, regenerative medicine aims to improve burn wound healing, minimize scarring, and restore functional skin.[8]

This study conducts a thorough bibliometric analysis and literature review on the application of regenerative medicine in burn injury management. We highlight the trends, hotspots, and article profiles. It aims provide insights for future research to enhance burn care management.

METHODS

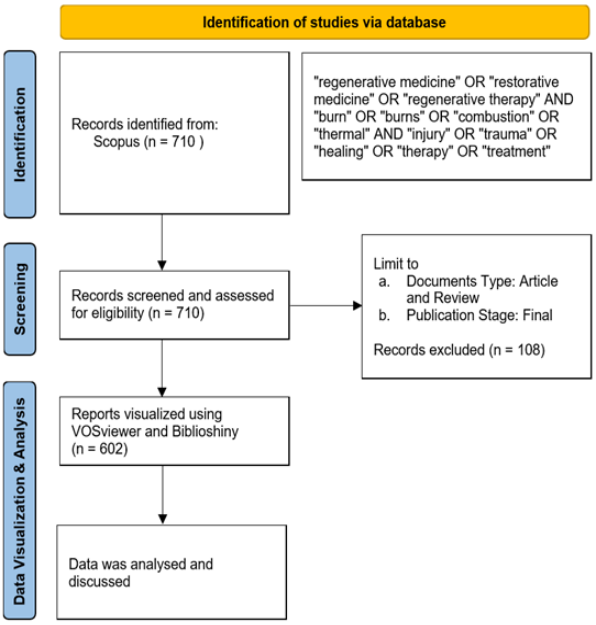

Figure 1. PRISMA 2020 flow diagram for bibliometric analysis

The data was acquired from the Scopus database through a search conducted with the keywords "regenerative medicine" OR "restorative medicine" OR "regenerative therapy" AND "burn" OR "burns" OR "combustion" OR "thermal" AND "injury" OR "trauma" OR "healing" OR "therapy" OR "treatment". The initial search obtained 710 documents. Subsequently, the search results were refined to include only documents classified as Article or Review document and in the Final publication stage, resulting in a finding 602 documents. The complete process is illustrated in Figure 1. The downloaded data were then analysed with VOSviewer (version 1.6.20) for mapping the cluster analysis and data visualization.[9] Additionally, study characteristics and thematic map analysis were examined using Biblioshiny software.

RESULTS

Study Characteristics

A total of 602 papers were gathered from 357 sources, covering the years 2004 to 2024. The annual growth rate stands at 10.96%, and the average document age is 6.07 years. The rise in collected papers is attributed to increased governmental interest in regenerative medicine, marked by a rise in federal funding and recognition of its pivotal role in healthcare. On average, each document receives 42.19 citations. The cumulative contributor count reaches 3,180 individuals, with 1,622 author-provided keywords. Notably, there are 42 single-authored documents, indicating a preference for individual contributions. However, with an average of 6.05 co-authors per document and an international co-authorship rate of 26.91%, collaboration among authors from various locations or institutions remains significant.

Annual Scientific Publications

The exported data provides a chronological overview of the annual publication trends from 2004 to 2024. Starting modestly with 2 articles in 2004, the number gradually increases over the years, showing occasional fluctuations. A noticeable uptick to 18 articles in 2012 is followed by a substantial rise to 82 articles in 2022, marking a significant peak. However, the trend reverses in subsequent years, with a notable decrease to 16 articles in 2024. This decline may be due to the fact that 2024 is only in its initial third period, allowing for additional articles to be added. This data highlights the dynamic nature of scholarly output over the analyzed period, capturing both periods of growth and decline in research productivity. The complete annual scientific productions were depicted in Figure 2.

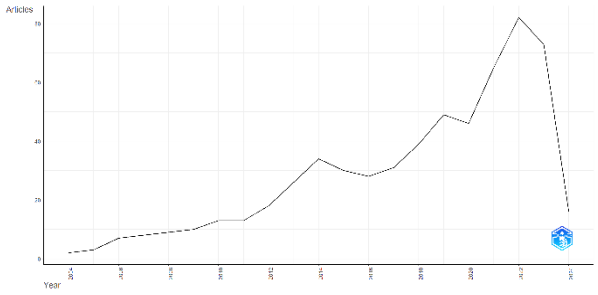

Figure 2. The annual publication of regenerative medicine in burn injury from 2004 to 2024

Authors, Institutions, and Country Data

The list of most relevant authors reveals individuals who have made substantial contributions to the research field, as evidenced by their publication counts. Leading the list are Zhang Y and Zhang Z, with a combined output of eight publications. Following closely are Applegate LA, Michetti M, Nilforoushzadeh MA, Raffoul W, Scaletta C, and Zhang X, each credited with seven publications, showcasing their steadfast dedication to scholarly inquiry and the dissemination of cutting-edge findings. Additionally, the inclusion of Amirkhani MA and Atala A, renowned for their scholarly prowess, with six publications each, underscores the depth and diversity of expertise within this esteemed group of authors. This data emphasizes the significant role these authors play in shaping discourse and advancing progress in their field of study, highlighting their valuable insights and unwavering commitment to scholarly inquiry.

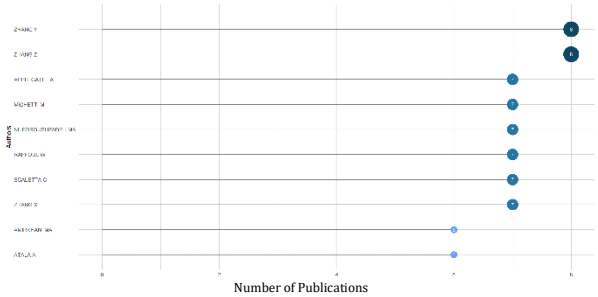

Figure 3. Top relevant authors for regenerative medicine in burn injury

The most significant affiliators represent a diverse array of institutions from around the globe. Leading the list is Lausanne University Hospital, with an impressive total of 72 articles, indicating its substantial contribution to scientific research. Close behind is the University of California, with 46 articles, demonstrating its prominence in academia and research endeavors. Tehran University of Medical Sciences also emerges as a notable affiliation, contributing 32 articles to the scientific literature. Furthermore, institutions such as University College London, China, and the University of Modena and Reggio Emilia have made substantial contributions, with 25, 24, and 22 articles respectively. The authors with the highest number of publications, ranking within the top ten in terms of productivity, were visualized in Figure 3. This data underscores the global collaboration and the pivotal role played by these institutions in shaping the landscape of scientific research.

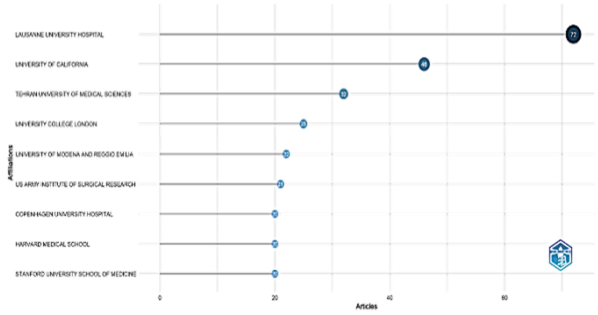

Figure 4. Top relevant affiliations for regenerative medicine in burn injury

The analysis of countries' scientific output reveals a diverse global landscape of research. Leading the list is the United States, with a formidable total of 527 scientific contributions, highlighting its enduring status as a powerhouse in scientific innovation and discovery. Following closely is China, with 426 publications, showcasing the country's rapid rise in the global scientific arena and increased investment in research and development. This data is unsurprising because the most relevant authors are Zhang Y and Zhang X, who both come from China. Italy and Iran also emerged as significant contributors, with 228 and 205 publications respectively, demonstrating their substantial contributions to advancing knowledge within their respective fields. Additionally, countries such as Japan, India, Brazil, Germany, South Korea, and France exhibit considerable scientific output, each contributing valuable insights to the collective pool of scientific knowledge.

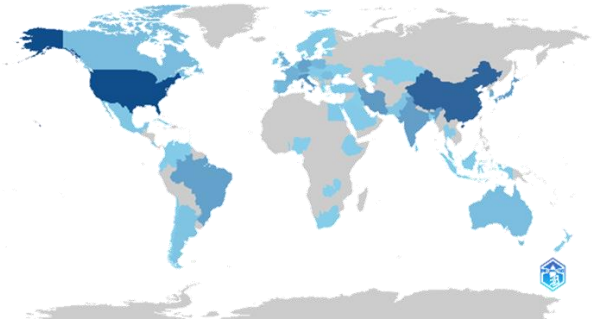

Figure 5. Top countries' scientific productions were visualized by contrasting shades on global map

Indonesia is positioned 34th in the ranking, indicating its scientific engagement with 13 publications, which could serve as catalysts for further research. Figure 5 visually represents this data on a global map using distinct shades. The darker shades on the Global Map indicate a greater publication rate ratio in comparison to the lighter shades. This examination offers valuable perspectives on the global distribution of scientific output, emphasizing the varied contributions of countries in fostering scientific advancement and innovation.

Research Hotspots and Frontier Trends in The Field of Regenerative Medicine

Figure 6 shows a network visualization map depicting keyword

occurrences related to regenerative medicine in burn injury. It illustrates the connections between clusters and the assessed problem areas. Researchers established a minimum threshold of five occurrences for keyword inclusion. Out of the initial 6811 keywords considered, only 85 met this criterion across four clusters.

Cluster 1 (red) predominantly encompasses topics related to materials and techniques used in biomedical applications. Keywords such as 3D printing, alginate, collagen, nanofiber, nanoparticles, biocompatibility, biomedical applications, graphene, hydrogel, photothermal therapy, hydroxyapatite, silk fibroin, scaffold, and chitosan are included. These topics primarily focus on materials and methods utilized in biomedicine, including manufacturing techniques, drug delivery systems, and scaffold materials for tissue engineering.

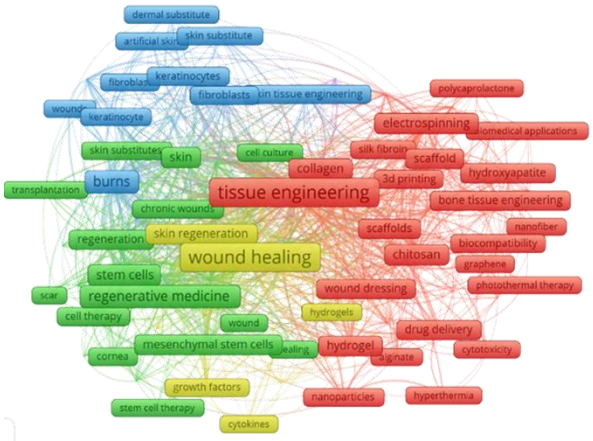

Figure 6. The visualization map of keyword occurrence

Cluster 2 (blue) encompasses topics related to burn treatment and skin substitutes such as skin tissue engineering, dermal substitute, artificial skin, keratinocytes, and fibroblast. These topics revolve around artificial or bioengineered products used to replace damaged skin in burn patients and the overall goal of promoting effective skin regeneration.

Cluster 3 (green) comprises topics associated with regenerative medicine focusing on cell-based therapies. Keywords such as regenerative medicine, stem cells, mesenchymal stem cells, stem cell therapy, cornea, transplantation, cell culture, chronic wounds, scar, and wound are included. This cluster focuses on regenerative medicine, including cell-based therapies, tissue regeneration, and engineering approaches to repair or replace damaged tissues.

Cluster 4 (yellow) focuses on topics related to wound healing and management, with a spotlight on the biological and therapeutic aspects of wound healing and regenerative medicine. Keywords such as wound healing, skin regeneration, growth factor, and cytokines are included. The integration of these biological components into advanced therapeutic strategies and biomaterials represents a significant frontier in improving patient outcomes in wound care and tissue regeneration.

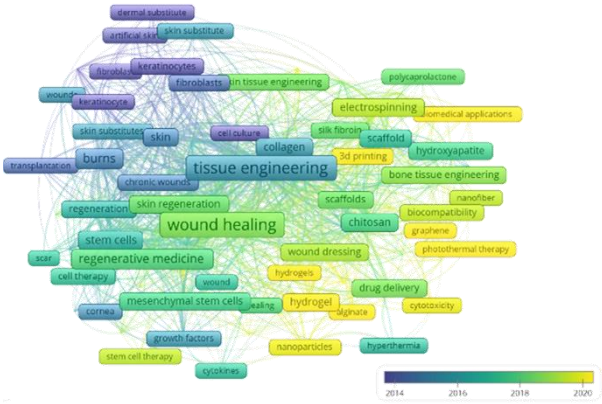

Figure 7. The visualization map of the keyword overlay by year. Yellow color indicates newer keyword distribution.

Figure 7 illustrates the evolution of research trends concerning regenerative medicine in burn injury. Prior to 2020, areas such as tissue engineering, wound healing, biomaterials, and stem cell therapy held significant importance in scientific research, with ongoing studies some time. Some topics, like stem cell therapy and tissue engineering, garnered substantial

recognition among other scientists, evident from the frequency of citations their articles received. Research on topics like wound healing and tissue regeneration also made a significant impact relative to the number of articles published on these subjects.

After 2020, researchers continue to explore topics like 3D printing, hydrogel, alginate, graphene, and photothermal therapy. The studies published after 2020 are more recent, indicating researchers' exploration of newer ideas and technologies. Although newer topics such as 3D printing, nanotechnology, and photothermal therapy may not have garnered as many citations yet, they hold promise for the future as interest in them grows. The impact of these emerging topics may vary, but they have the potential to gain prominence as they become more widely recognized.

Overall, scientific research both before and after 2020 has focused tissue engineering and wound healing, while also venturing into newer fields like 3D printing and nanotechnology. This shift towards exploring new technologies underscores the continuous progress and dynamic nature of biomedical research.

Thematic Map Analysis

We conducted a thematic mapping analysis to provide valuable insights for researchers regarding potential avenues for future research in specific thematic areas.[9] The Thematic Map was created using author keywords and formulated based on a two-dimensional matrix that incorporates two distinct metrics: centrality (X-axis, indicating theme relevance) and density (Y-axis, representing theme development level).

In our thematic analysis of Figure 8, each quadrant of the thematic map conveys distinct characteristics of research themes within the field. Starting from the lower right quadrant, we come across the basic themes, which show a significant balance of low density and high centrality. This is highly important in the field of research. Clusters such as regenerative medicine, wound healing, and tissue engineering are fundamental areas that have been extensively studied and form the basis of our understanding. Interestingly, a cluster involving drug delivery, chitosan, and scaffolds, which are not core keywords, also appears in this quadrant.

Conversely, the lower left quadrant encompasses Emerging or Declining Themes, representing new or evolving topics that may either rise to prominence or diminish from the research arena over time. Here, clusters such as graphene and stem cell therapy illustrate themes currently under exploration that could potentially influence future research trajectories.

Moving to the upper left quadrant, we encounter Niche Themes, characterized by high density but lower centrality. These themes are highly developed yet somewhat isolated within the broader research discourse. Clusters such as nanomedicine, electrospinning, nanofibers, and silk fibroin represent specialized areas of research that have received significant attention and advancement despite their relatively limited integration into mainstream research agendas.

Finally, in the upper right quadrant lie the Motor Themes, distinguished by their high density and centrality, indicating their pivotal role and extensive exploration within the field. These themes serve as driving forces behind research endeavors, representing well-established and essential aspects of scientific inquiry. Clusters such as fibroblasts, keratinocytes, biotechnology, collagen, skin regeneration, and adipose-derived stem cells exemplify themes that are not only highly developed but also crucial to advancing our understanding and applications within the field of study.

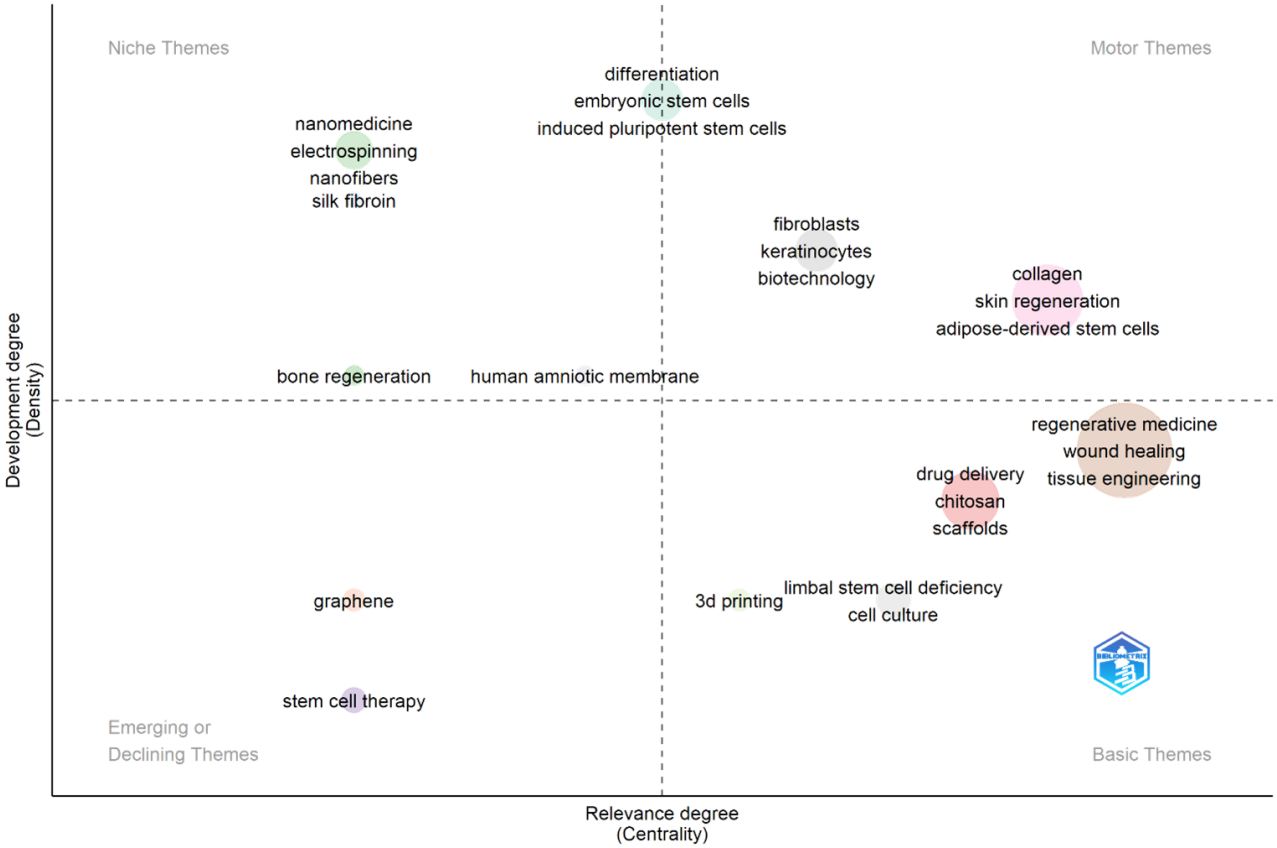

Figure 8. Thematic Map analysis

DISCUSSION

Burn injuries are defined as tissue damage caused by exposure to thermal, chemical, electrical, or radiation sources. According to the World Health Organization (WHO), burns can be classified based on their depth and extent of tissue involvement, ranging from superficial to deep and involving varying percentages of the total body surface area.[10] Epidemiological studies show a significant global burden of burn injuries, with around 180,000 deaths annually and millions living with lifelong disabilities.[11] Children and young adults are particularly at risk, often suffering burns from scalds and flames, while older adults are more likely to experience burns from hot liquids and fires.[12] Common causes of burn injuries include residential fires, occupational accidents, electrical malfunctions, and chemical exposures.[13]

Burn injury management usually requires a multidisciplinary approach involving wound care, infection prevention, fluid resuscitation, and rehabilitation. Conventional treatment methods include debridement, topical antimicrobial agents, skin grafting, and supportive care.[14] Although these interventions have improved survival rates and functional outcomes, they still have limitations. Challenges such as wound infections, scarring, contractures, and long-term disability persist, emphasizing the necessity for innovative therapeutic approaches to improve burn wound healing and tissue regeneration.[15]

Regenerative therapy for burn injuries presents several areas that require further research to advance treatment options and optimize patient outcomes. One critical area of investigation is the development of biomaterials specifically tailored for burn wound healing. Researchers are exploring innovative materials that mimic the native extracellular matrix (ECM) to promote cell adhesion, proliferation, and differentiation at the wound site. By optimizing the mechanical, structural, and biochemical properties of biomaterials, there is potential to enhance wound closure, prevent infection, and minimize scar formation in burn patients.[16,17]

Another crucial aspect of research is gaining a deeper understanding of the underlying regenerative mechanisms involved in wound healing. This includes elucidating the roles of stem cells, growth factors, and immune cells in tissue regeneration and inflammation modulation. By unraveling these mechanisms at a molecular and cellular level, researchers can develop targeted therapies that accelerate wound healing and promote more robust tissue regeneration in burn injuries.[18]

Furthermore, integrating different therapeutic approaches, such as stem cell therapy, growth factor delivery, and tissue engineering, requires comprehensive investigation. Researchers are exploring how to combine these strategies synergistically to maximize treatment efficacy, reduce healing time, and improve functional outcomes for burn patients. Clinical translation of these promising research findings into practice is essential, emphasizing the importance of conducting rigorous clinical trials to evaluate safety, efficacy, and feasibility in real-world settings.[19]

The sustainability of regenerative therapy technologies holds significant promise for improving outcomes in burn injury care, particularly in regions with limited resources. In the context of burn injuries, regenerative therapies offer innovative approaches to accelerate wound healing, reduce scarring, and improve functional outcomes.[20] However, the adoption and sustainability of these technologies in low-resource settings depend on addressing specific challenges related to cost, infrastructure, and capacity building.

For burn injury patients, optimizing the cost-effectiveness of regenerative therapies is paramount to ensure accessibility and affordability. Innovations aimed at reducing production costs and streamlining supply chain logistics can enhance the feasibility of incorporating regenerative treatments into burn care protocols.[21] Furthermore, investment in healthcare infrastructure, including facilities for cell culture and bioprocessing, is essential for scaling up regenerative therapies to meet the demand for burn injury treatment.

Capacity building initiatives that empower local healthcare providers and researchers to engage with regenerative medicine technologies are critical for sustainable implementation. By training professionals in burn care centers to utilize regenerative therapies effectively, countries can strengthen their healthcare systems and improve outcomes for burn patients. Integrating regenerative therapies into existing burn injury care protocols requires aligning regulatory frameworks and policies with local health systems to ensure equitable access and sustainable utilization.

More research is needed to establish definitive superiority across all clinical scenarios, existing evidence suggests that regenerative therapies hold promise for enhancing wound healing, reducing pain, and improving quality of life for patients with burns and chronic wounds. a

randomized controlled trial by Hendry S et al. (2024)[22] compared the use of autologous skin cell suspension (ASCS) therapy with standard wound care in patients with severe burns. The study demonstrated faster wound closure, reduced pain levels, and improved scar quality in the ASCS therapy group compared to the control group. Similarly, a study by Ramaswamy RSH et al. (2018)[23] reviewed several clinical trials and concluded that regenerative therapies, such as platelet-rich plasma (PRP) and stem cell-based treatments, significantly improved wound healing outcomes compared to conventional treatments. In terms of patient-reported outcomes and quality of life, studies have shown positive results with regenerative therapies. For instance, a study by Malekzadeh H et al. (2023)[24] evaluated the impact of adipose-derived stem cell therapy on chronic wounds and found significant improvements in pain relief, wound healing rates, and overall patient satisfaction compared to standard wound care approaches.

Regenerative therapy offers a promising shift in burn injury management, leveraging the body's natural healing mechanisms to facilitate tissue repair and regeneration. Essentially, it involves utilizing biological agents like stem cells, growth factors, and biomaterials to stimulate tissue regeneration and restore functional integrity.[25] These approaches target the underlying pathophysiology of burn injuries, such as inflammation, impaired angiogenesis, and fibrosis, to promote healthy tissue regeneration and minimize scar formation.[26] In simpler terms, regenerative therapy for burn injuries can be classified into four main areas: Tissue Engineering, Biomaterials, Cell-based therapies, and Bioactive Factors.

Tissue Engineering

Tissue engineering presents innovative solutions for addressing the structural and functional deficits associated with burn injuries. Engineered skin substitutes, consisting of cells, scaffolds, and bioactive factors, demonstrate significant potential in promoting wound healing and tissue regeneration.[27] Recent advancements in tissue engineering techniques, including 3D bioprinting and decellularized matrices, enable the fabrication of complex tissue constructs resembling native skin, offering a promising alternative to traditional skin grafts in burn injury management.[28]

Cell-Based Therapies

Cell-based therapies show promise in enhancing wound healing and tissue regeneration for burn injuries. Mesenchymal stem cells (MSCs) and adipose-derived stem cells (ASCs) exhibit therapeutic potential due to their immunomodulatory and regenerative properties.[29] Clinical studies demonstrate the effectiveness of MSC and ASC-based therapies in promoting wound closure and reducing scar formation in burn injury patients.[30] Advances in cell culture techniques, such as microcarrier-based systems and bioreactor culture, facilitate large-scale expansion and delivery of therapeutic cells for clinical applications.[31]

Adipose-based cell therapy has emerged as a promising approach in the treatment of burn injuries. Adipose-derived stem cells (ADSCs) obtained from fat tissue have shown potential for promoting wound healing and tissue regeneration in burn patients. These stem cells can differentiate into various cell types and release growth factors that stimulate angiogenesis and modulate inflammation, contributing to accelerated wound closure and reduced scar formation. Clinical studies have demonstrated the safety and efficacy of

ADSC-based therapies in improving burn wound healing and functional outcomes.[32]

Biomaterials

In addition to cell-based therapies, biomaterials play a crucial role in burn wound care, particularly in intensive care units (ICUs). Biomaterials such as hydrogels, films, and nanofibers are used as wound dressings to create a favorable environment for healing, protect the wound from infection, and promote tissue regeneration. These materials can provide moisture balance, control inflammation, and deliver therapeutic agents to enhance wound healing. In ICU settings, advanced biomaterials are essential for managing complex burn injuries and preventing complications.[33]

Biomaterials play a crucial role in facilitating tissue regeneration and providing structural support for burn wound management. Hydrogels, scaffolds, and nanomaterials are utilized to create an optimal wound healing environment.[34] Recent developments in biomaterial design focus on improving biocompatibility, mechanical properties, and bioactivity to enhance tissue regeneration.[35] Additionally, biomaterial-based dressings and coatings are engineered with antimicrobial properties to reduce infection risk and promote wound healing.[36]

Bioactive Factors

The controlled release of bioactive factors, including growth factors and cytokines, offers a promising approach to stimulate tissue regeneration in burn injuries. Delivery systems based on biomaterials allow for the gradual release of bioactive factors at the injury site, promoting cell proliferation, angiogenesis, and remodeling of the extracellular matrix.[17] Recent research has focused on refining the timing and distribution of bioactive factor release to maximize therapeutic benefits while minimizing adverse effects.[33] Additionally, innovative methods such as gene therapy and exosome-based therapies hold potential for delivering bioactive factors to the wound site with precision.[37]

Recent advancements in regenerative approaches, including tissue engineering, biomaterials, cell-based therapies, and bioactive factors, hold great promise for improving outcomes in burn injury management. By harnessing the synergistic effects of these innovative strategies, researchers and clinicians are poised to revolutionize the treatment landscape for burn injury patients in the coming years.

3D Printing and Nanotechnology

The convergence of 3D printing and nanotechnology presents exciting opportunities to advance burn injury care. By harnessing these technologies, researchers are exploring innovative approaches to wound healing, tissue regeneration, and personalized treatments that could significantly improve outcomes and quality of life for burn patient. Advancements in 3D printing and nanotechnology hold promising implications for burn injury treatment and recovery. One notable application is the development of customized skin grafts using 3D bioprinting technology. Researchers are exploring the use of patient-specific cells and biomaterials to create bioengineered skin substitutes that closely mimic natural skin properties. These advanced grafts could improve wound healing and reduce scarring in burn patients, offering personalized solutions tailored to individual injury characteristics.[38]

The integration of 3D printing with microfluidics also offers potential benefits for burn injury management. Microfluidic devices can be used to create precise delivery systems for administering

therapeutic agents or growth factors directly to burn wounds, optimizing treatment efficacy and minimizing adverse effects.[39-41]

Additionally, nanotechnology plays a crucial role in enhancing wound dressings and topical treatments for burn injuries. Nanomaterials, such as nanoparticles and nanofibers, can be incorporated into dressings to enhance antibacterial properties, promote wound healing, and prevent infection. The controlled release of therapeutic agents from nanocomposite materials can provide targeted and sustained treatment at the wound site, improving outcomes for burn patients.[42]

Photothermal Therapy

Photothermal therapy in burn injury involves using light energy, typically in the near-infrared range, to generate heat within tissues. This heat can selectively target damaged tissue, promoting wound healing and tissue regeneration while minimizing damage to surrounding healthy tissue. In the context of burn injuries, photothermal therapy can enhance drug delivery by increasing the permeability of the skin barrier, allowing therapeutic agents to penetrate deep into the wound site. Additionally, photothermal therapy can induce hyperthermia, which stimulates cellular responses such as the expression of heat shock proteins, further aiding in tissue repair. Overall, photothermal therapy offers a promising approach to improve the treatment outcomes of burn injuries by combining targeted drug delivery with localized heating effects to promote healing and reduce scarring.

Bolouki N et al. (2021)[43] studied the potential of photothermal therapy via cold atmospheric plasma (CAP) for improving drug delivery effectiveness in treating large and irregular burn wounds. They utilized CAP-induced crosslinking with methylcellulose (MC) to enable sustained delivery of therapeutic substances like platelets (SP) and polyethyleneimine-polypyrrole nanoparticles (PEI-PPy NP). The CAP-treated SP-PEI-PPy NP-MC polymer complex demonstrated enhanced mechanical properties, biocompatibility, sustained drug release, and near-infrared (NIR)-induced hyperthermia effects. This innovation highlights the potential of photothermal therapy in engineering carrier designs for burn treatment, offering improved drug delivery effectiveness and targeted heat delivery. This method holds promise as an innovative solution for future bioengineered carrier designs, facilitating enhanced mechanical properties, biocompatibility, sustained drug release, and NIR-induced hyperthermia effects to promote heat shock protein expression and drug permeation into deep lesions.

The use of stem cells or genetic manipulation in treating burn injuries raises important considerations related to safety, efficacy, and ethical implications. One significant concern is the risk of tumorigenicity associated with stem cell therapies, where the uncontrolled growth of stem cells or genetically modified cells may lead to tumor formation or other adverse effects. Additionally, genetic manipulation techniques like gene editing carry the risk of unintended genetic changes or off-target effects, which could pose long-term safety concerns for patients.[44]

Ethical considerations are paramount in the use of these advanced therapies. Obtaining informed consent from patients or research participants is crucial, ensuring they understand the experimental nature of the treatments and potential uncertainties involved. There are also ethical implications regarding resource allocation, ensuring equitable access to experimental therapies without exacerbating healthcare disparities.[45]

To address these concerns, robust regulatory and oversight processes are in

place. Regulatory approval from government agencies, such as the FDA or equivalent bodies, is required before clinical trials can proceed. Institutional review boards (IRBs) or ethics committees evaluate study protocols, informed consent procedures, and participant protections to ensure compliance with ethical standards. Continuous monitoring and reporting of clinical trials are essential to track safety and efficacy outcomes and promptly address any adverse events.[46-48]

Guidelines and standards established by regulatory agencies and professional organizations further ensure that research adheres to ethical principles and patient safety standards. Collaboration among researchers, regulatory bodies, and ethics committees is critical to advancing innovative therapies while safeguarding patient welfare and upholding ethical standards in stem cell and genetic therapies for burn injury treatment.

Efforts to ensure the accessibility and inclusivity of regenerative therapies for all patients are crucial for advancing equitable healthcare practices. One key strategy involves research and development focused on creating cost-effective regenerative therapies that can be produced at scale. Innovations in manufacturing techniques, such as 3D bioprinting and automated cell processing, aim to reduce production costs and increase the availability of regenerative products, making them more accessible to diverse patient populations.

Another important aspect is the promotion of diversity in clinical trials and evidence generation. Inclusive clinical studies that represent a broad range of patient demographics, including diverse ethnic and socioeconomic backgrounds, are essential. By ensuring diverse representation in research, clinicians and researchers can better understand how regenerative therapies perform across different patient groups and tailor treatments accordingly.

Regulatory policies and reimbursement strategies also play a pivotal role in enhancing accessibility. Governments and regulatory agencies can streamline approval processes for innovative therapies, provide incentives for research and development in regenerative medicine, and ensure adequate reimbursement mechanisms. These policies facilitate patient access to cutting-edge treatments and promote health equity. [49,50]

Collaborative efforts across research, regulatory, and healthcare sectors are essential for ensuring the accessibility and inclusivity of regenerative therapies. By addressing barriers and implementing inclusive practices, healthcare systems can improve patient access to innovative treatments and advance health equity on a global scale.

Strength and Limitations

Bibliometric analysis tools like VOSViewer and Biblioshiny provide valuable insights into scholarly communication networks. VOSViewer excels at visualizing key patterns in network literature, such as topic clusters and keyword relationships. Biblioshiny, with its user-friendly interface, enhances accessibility by presenting literature data like the distribution of publication years, publication types, and the frequency of specific authors. However, the manual input required to determine cluster sizes in VOSViewer can influence how networks are colored, and Biblioshiny's reliance on predefined metrics may not fully capture the complexity of scholarly impact, potentially missing important aspects of academic influence beyond citation counts. Therefore, researchers should use these tools judiciously, supplementing their insights with contextual understanding. These tools offer a novel approach to

bibliometric analysis by combining powerful visualization (VOSViewer) and user-friendly data presentation (Biblioshiny), significantly enhancing the ability to identify and understand complex scholarly communication networks. Their innovative features allow for more nuanced and accessible analyses compared to traditional bibliometric methods, fostering deeper insights and broader usage across various research disciplines.

CONCLUSION

The field of regenerative medicine in burn injury management is poised at the cusp of transformative advancements. By leveraging the synergistic potential of tissue engineering, cell-based therapies, biomaterials, and bioactive factors, this innovative approach offers a multi-faceted strategy to enhance wound healing, reduce scarring, and improve functional outcomes. As research continues to evolve, integrating these therapies into clinical practice will require rigorous clinical trials to ensure safety, efficacy, and feasibility. The future of burn care lies in the sustainable adoption of these cutting-edge technologies, promising a significant leap forward in patient care and recovery.

Through bibliometric and visualization methods, we concluded the following: (1) The number of publications in the field of regenerative medicine for burn injuries has significantly increased over the past two decades. (2) Our analysis underscores the critical role of 3D printing and nanotechnology. Future research should prioritize these areas, foster international collaboration, and increase funding to stimulate innovation in burn care. (3) Given that this study relied solely on the Scopus database, we recommend that future research incorporate a variety of databases (e.g., PubMed, Web of Science, and Springer) to capture a broader spectrum of high-quality scientific contributions.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this article.

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AUTHOR CONTRIBUTION

Data collection, analysis and interpretation of the results was primarily undertaken by NAR and MYBP, under the supervision of SD. GEO, LPD, PS were critical revision of the article and proofreading. All authors contributed to the drafting of the manuscript and approved the final version for submission.

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Authors' Contributions

All of the authors have contributed to the planning, data collection and analysis, writing, and approval of this paper for the publishing stages of the research.

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1. ISSVA Classification for Vascular Anomalies. 2018. (Accessed 5 October 2019). Available from: https://www.issva.org/UserFiles/file/ISSVA-Classification-2018.pdf
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Reference in a proceeding:

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