ARTÍCULO DE REVISIÓN

Medical technologies in intraoperative pressure ulcers: A literature review

Tecnologías médicas en úlceras por presión intraoperatorias. Una revisión de la literatura.

Daniel San-Juan,[a,*] Raul Alejandro Miranda,[b] Antonio Alonso Pascacio,[c] Sergio Mayorquin,[d] Miguel Ángel Sosa[e]

Recibido: 01 de febrero de 2021
Aceptado: 17 de febrero de 2021

PALABRAS CLAVE:

Úlceras por decúbito, úlceras por presión, sensores.

Resumen

Las úlceras por presión (UP) son lesiones isquémicas de los tejidos que surgen principalmente como resultado de las fuerzas de compresión y cizallamiento entre la piel y una superficie rígida. En la actualidad se considera un problema de salud pública, a menudo como una complicación durante el periodo quirúrgico. Se conocen factores de riesgo intrínsecos y extrínsecos que predisponen a la población a sufrir estas lesiones. Se han desarrollado varias medidas preventivas para las tres fases del proceso quirúrgico: Preoperatoria, intraoperatoria y postoperatoria. Pocos estudios han abordado los desarrollos tecnológicos en las medidas preventivas de las UP como potencial evaluación de dichas lesiones. Este artículo pretende revisar los principales conceptos en el marco de las UP, los factores de riesgo, el enfoque terapéutico y los recientes avances tecnológicos en la prevención de las UP en el periodo intraoperatorio. Encontramos que es necesario redoblar los esfuerzos para reducir la incidencia de las UP durante un procedimiento quirúrgico, no existiendo en la actualidad evidencias suficientes ni soluciones definitivas, aunque se han realizado algunas aportaciones y estudios para potenciar el desarrollo tecnológico en materia de prevención de las UP.

KEY WORDS:

Bedsores, decubitus ulcers, pressure ulcers, sensors.

Abstract

Pressure ulcers (PU) are ischemic lesions of the tissues that arise primarily as a result of compressive and shear forces between the skin and a rigid surface. It is currently considered a public health problem, quite often as a complication during the surgical period. There are known intrinsic and extrinsic risk factors that predispose the population to these lesions. Several preventive measures have been developed for the three phases of the surgical process: Preoperative, intraoperative, and postoperative. Few studies have addressed the technological developments in the preventive measures of the PU as a potential assessment of such lesions. This article aims to review the main concepts in the framework of PU, risk factors, therapeutic approach, and recent technological advances in the prevention of PU in the intraoperative period. We found that is necessary to redouble efforts to reduce PU incidence during a surgical procedure, insufficient evidence and no definitive solutions is existing nowadays even though some contributions and studies have been made to enhance technological development in terms of PU prevention.

[a] Instituto Nacional de Neurología y Neurocirugía Manuel Velasco Suárez, México.
[b] Universidad Autónoma del Estado de México, México.
[c] Benemérita Universidad Autónoma de Puebla, México.
[d] Universidad Autónoma de Nayarit, México.
[e] Universidad de Guadalajara, México.
* Autor para correspondencia: pegaso31@yahoo.com

Introduction

Pressure ulcers (PU), also called decubitus ulcers (although not limited to this anatomical position), are deep skin and soft tissue excavations caused by the progressive occlusion of blood vessels underlying the area of injury. This occlusion causes ischemia and the latter, necrosis [1]. It should be noted that PU are more frequent in those sites that are adjacent to a bone prominence, given the potential bilateral compression exerted [2].

The development of PU depends to a large extent on the presence of associated risk factors such as age, weight, nutritional status, and comorbidities. However, every patient destined to undergo a surgical procedure is potentially prone to develop PU [3].

The PU represents one of the main postsurgical complications and therefore the pre-operative and intraoperative preventive approach is of great importance for a favorable outcome [4]. The duration of the surgery and the environment in the operating room are the determining factors for the development of PU [5].

The current literature focuses on preventing these PU after the Medicare & Medicaid policies of the United States, published in 2008 related to not covering the expenses of the PU acquired during the hospitalization, for which many health centers have implemented measures for the prevention of PU [6]. PU are classified by the American NPUAP (National Pressure Ulcer Advisory Panel) scale. Staging consists of four levels according to the depth of the lesion, and therefore its severity. In the operating room, the most common PU are stage I and II. However, if they are not assessed and approached correctly, they can become stage III and IV ulcers [3]. PU management measures are based on their severity and consist mainly of weight redistribution, debridement, topical coverage, and, in case of infection, antibiotic treatment [7].

1.1 Epidemiology

PU has been classified as a serious medical condition, in the United States, it is estimated that it affects approximately 2.5 million people, which generates costs of up to 16 billion dollars per year in treatment [8]. This incidence of PU development ranges from 12% to 45% in surgical patients, [9] and varies significantly depending on the clinical context and exposure to risk factors, which represent the main predictor [10,11].

Patients with spinal cord injury are the population with the highest risk (25-66%) of developing PU due to the combination of prolonged time in the operating room with immobility and decreased sensitivity in the recovery room [12]. Among the most affected are elderly patients, and the patients undergoing orthopedic and cardiac surgery [13] Primiano et al., [10] reported in 2011 that PU occurs more than twice in male patients than in female patients (12.0% vs. 4.8%, respectively) undergoing some prolonged surgical procedure (> 3 h), this associated with intrinsic and extrinsic factors such as the age of the patient, comorbidities, immobility, nutrition, friction, height, and weight.

The main risk factors are described as extrinsic and intrinsic:

- Extrinsic: Moisture of the environment, lotions, support surface.
- Intrinsic: Advanced age of the patient, patient's temperature, the patient's size, nutritional status, and comorbidities.

Classification

The clinical presentation of the PU depends on the severity of them, and they are classified by pressure injury classification systems depending on the geographic region. In this review, we selected the NPUAP (National Pressure Ulcer Advisory Panel) Classification System from 2016 to classify the severity of pressure ulcers [14]. This classification divides PU into 4 stages according to the depth and macroscopic aspect of the lesion and a fifth category for unstageable lesions [Table 1].

NPUAP Scale	
Stage 1	The skin is integrated, with cutaneous erythema that does not pale when the pressure is removed, it may be accompanied by edema, pain, or insensitivity.
Stage 2	Loss of the natural thickness of the skin involving the epidermis and/or dermis presents as a superficial ulcer type abrasion.
Stage 3	Total loss of the thickness of the skin, involving even the subcutaneous tissue, but does not exceed beyond the underlying fascia, there is the presence of necrosis.
Stage 4	It is the total and extensive loss of tissues, with necrosis of muscle and connective tissue (ligaments, fascia, and joint capsule), cavitations, and tunnels that can occur in this stage.

1: Ulcers staging scale, NPUAP (National Pressure Ulcer Advisory Panel)

Pathophysiology

PUs are lesions that involve the skin and underlying tissues, occur for the prolonged time the patient spends at the table during surgery operations with friction between two hard planes, the skin of the subject and the external surface, all the above triggers tissue ischemia due to decreased blood supply in areas of higher pressure, that is, those adjacent to a bony prominence [1]. The tissues can maintain an infusion of vascular microcirculation at a pressure of 12-32 mmHg, that is, the capillary pressure [15]. This pressure can be obtained from a micro-pressure system using an air-water interface [16]. It has been stipulated that PUs are caused by the occlusion of the circulation, and since the blood capillaries represent the last structural subsystem of blood vessels that provide tissue nutrition, the expiration of such pressure determines in part the appearance of ulcers by pressure [15]. Added to this, another factor of importance is time; the ulcers begin their formation from 1 to 2 hours of continuous immobility by the patient [1]. It is worth mentioning that there are factors that modify the time of appearance of PUs; patient's morphology, skin characteristics, compressive surface characteristics, together with friction and friction forces, failure of the hyperemia reactive cycle, the level of involvement of lymphatic drainage, as well as the risk pre-established by intrinsic risk factors and/or extrinsic with which the patient complies [17].

- Time – Pressure threshold

One of the most relevant concepts in the etiopathogenesis of PU is the pressure time threshold, representing the relationship between the pressure exerted on the body surface and the time in which the patient remains immobilized continuously. This threshold looks for a relationship that determines the cutoff point. However, as already mentioned, PUs are not only caused by direct compression but by many other factors (see pathophysiology), the great variability both at the intrinsic level (corresponding to the patient) and extrinsic level (from the external environment), make it extremely difficult to determine a universal pressure threshold [18]

Kosiak., [19] proposed in 1959 a time-pressure curve from experiments with canines to which he subjected pressure measurement by interference. This study led to another in humans conducted in 1976 by Reswick and Rogers., [20] who from a sample of 980 patients proposed a time-pressure curve using such as Kosiak, an interference pressure device, based on the technology of a sphygmomanometer. It is worth mentioning that the study by Reswick and Rogers is limited given that the interference pressure measurements do not reflect the loads to which the internal tissues are subjected, among which the muscle fibers stand out, which are the most affected in the PU [7]. To overcome the aforementioned difficulties, some researchers (21-24), have made an effort to propose more precise thresholds through experiments that focus on determining the load of muscle tissue tolerance.

This was accomplished by implementing imaging techniques such as magnetic resonance and histopathological analysis, by observing the level of damage produced in muscle fibers after the compression of these by a piston with determined pressures during variable periods [7]. Since it has not been possible to reach a consensus regarding the pressure-time threshold. Coleman., [17] propose the concept of '' individual damage threshold '', which, far from being a defined figure, is the conjunction of the main factors involved in the development of PU, as are the risk factors, the mechanical load duration, the type of load and force (friction and pressure), the repair capacity of the tissue of each patient, the individual morphology, the thermal properties, among others.

- Preoperative clinical approach

It requires a complete physical examination and a comprehensive assessment of exposure to intrinsic and extrinsic risk factors. Other aspects of importance to take into account are the psychosocial, socioeconomic status, and level of vulnerability (e.g. elders). This is because patients with the PU are individuals who most likely do not have access to adequate health care services and/or the caregiver did not receive the relevant training [25]. The staging of the lesion should be performed according to its location, size, and depth. You should also look for indications of evolution such as exudate, odor, evidence of necrosis, and/or infection [12].

For the perioperative context, the Braden scale, [26] can be used to evaluate the development of PU. It consists of six criteria: sensory perception, humidity, activity, mobility, eating habits, and friction/friction forces. The Braden scale is useful; however, it is not recommended to use it as the only option when addressing the postoperative risk of presenting PU; [27] other useful alternatives to help in the estimation of risk are the scales of Waterlow, Cubin -Jackson, Norton, among others [28].

Treatment

The main treatment measures for ulcerative lesions already established by pressure are the following:

1. Release of pressure
2. Infection control
3. Debridement of necrotic tissue
4. Covers and healing

The release of pressure consists in the redistribution of the patient's weight, this is commonly done by changing the position of the individual with some regularity,

however, during surgery, this is usually not possible. You can also resort to gel pads or beds specialized in the redistribution of compression loads. The control of the infection is achieved through the placement of drainages and depending on the severity of the infection it is possible to opt for the administration of antiseptic agents (e.g. iodine, silver sulfadiazine, or hydrogen peroxide) or IV antibiotics. The use of the latter is limited to those patients with significant cellulitis and who show signs and symptoms of severe infection. Debridement of necrotic tissue is essential in PU management. This can be done mechanically through cleaning with pressurized irrigation. There are other options such as ultrasound [3] and laser [29]. The lesion covers are materials designed to be placed on the ulcer and help in healing and act as protective barriers:

- Colloid covers
- Alginate covers
- Silver nanoparticle covers
- Topical agents (creams / ointments)

Some other management measures consist of the administration of negative pressure, reconstruction with tissue grafts, and administration of hyperbaric oxygen [12].

Prevention

- Patient evaluation measures:

Patients who undergo surgery should be managed appropriately from admission and throughout the hospital stay as initial measures of ulcer prevention. Patients should be reevaluated regularly, especially those who have undergone surgical procedures. Patient evaluation measures can be divided into 3 phases: preoperative, intraoperative, and postoperative.

- Preoperative

· Patient risk factors- intrinsic factors.
· Optimal nutritional status.
· Measurement and maintenance of normothermia.
· Minimize exposure to moisture and keep all parts of the skin that are in contact with a surface dry during the surgical procedure.
· Reduce or eliminate friction.

- Intraoperative

· Position the patient appropriately according to the type of surgery
· Protect the most sensitive areas' to pressure in the different positions: supine, prone, and lateral
· Peripheral perfusion must be ensured

- Postoperative

· Remove adhesives and gel from the patient's skin immediately after the surgical procedure.
· The report observed changes or abnormalities.
· Ensure early mobilization after surgery.
· Favor a low humidity environment, less than 40%.
· Keep the head of the bed at 30 degrees, or as allowed by the patient's medical conditions [30].
· Change the patient's position at least once every two hours.

- Technological Advances in the Prevention of Pressure Ulcers:

Technological solutions have been proposed through prospective studies for the prevention of PU using mattresses, cushions, or smart beds during the surgical intervention or the hospitalization of the patient, which increases the tolerance to pressure and uniformly applies pressure to the human body [13,31]. Feuchtinger., [32] conducted a randomized controlled trial to test the effect of a 4 cm thermoactive viscoelastic foam pad on the operating room table to prevent pressure ulcers during cardiac surgery. The study consisted of a sample of 175 patients divided into 2 groups compared, the first with 90 patients operated on the ordinary surgical table against 85 patients operated on using the foam pad, the results concluded that the use of this foam for redistribution of weight increased the temperature and humidity in the tissues of the patient in contact with the table so that the incidence of PU contrary to what was expected, resulted in a slight increase (17.6%) than in those who did not use the device (11.1%) so it is concluded that the use of this foam pad is not recommended for the prevention of PU, and it also is counterproductive.

Given that the identification of the risk of developing PU and clinical judgment use subjective criteria, it is necessary to have new prevention technology tools applicable to operating theater environments [31].

The general idea of using pressure sensors in sheets is not new, however, current needs require continuous monitoring. The company Wellsense of the United States is a leader in the introduction of technology for monitoring bed pressure, offering a continuous monitoring solution, which provides feedback, data, and visual or audible alerts that help clinicians to improve its effectiveness and efficiency, achieving a significant reduction of 88% in reducing the risk of developing pressure injuries [31,33]. However, to date, all these Wellsense devices have not been used in the operating room environment [31,34]. Ajami S., [34] conducted a review from 1974 to 2014 of the development of a network of wireless sensors that could be used in the beds of hospitalized patients, finding 45 articles and analyzing 37 of those 45, concluding that beds smart and mattresses, isolated or in conjunction with other technologies can provide innovative information that improves

the comfort and safety of patients, reducing the costs associated with the treatment of PU in intensive care. Allegretti et al., [35] tested a force sensor system in the form of mesh (Force- Sensing Array 4.0), which was placed on the back of 5 patients undergoing liver transplantation, allowing its monitoring with this device for an average of 10.2 hours both in the operating room as well as in the recovery room. This made possible a pressure and temperature monitoring reached by contact with the surgical table. Likewise, it was possible to demonstrate that the sacral area is the most vulnerable to the PU because it reaches pressures from 24 to 76 mmHg and an average temperature of 37.5 ° C. [35]. A recent meta-analysis included 9 prospective clinical studies (n = 6 to 627 patients) that used pressure sensors placed on the patient's bedsheet, or over the wheelchair sitting surface and in one case they applied a sensor on the patient's skin and showed that it is possible to reduce the risk of developing new PU by 88% in hospitalized patients [31]. However, the prevention of PU in the operating room is a poorly attended area and has challenges, since the patient is usually naked, in a bed of small dimensions, sometimes with empty spaces or different sizes, unusual anatomical positions, bone protection is offered through pads, masks or silicone gels., [36] so using sensors on clothing, sheets or textiles of patients offers special challenges [34].

Another meta-analysis on the use of surfaces for the redistribution of pressure in high-risk patients found that patients who used support surfaces (mattresses) had a significant decrease in the incidence of PU associated with surgery, compared with those who used conventional bed surfaces. However, the incidence of intraoperative use did not decrease, although, in the postoperative period, its use is controversial [37]. It is also worth mentioning that due to special conditions in the surgery room, the particular pathogenesis of PUs related to surgery may be different from that which occurs in patients hospitalized in conventional beds, e.g. the effect of anesthetics [37]. In patients with a high risk of PU related to surgery, placing them on a surface of redistribution of pressure during the postoperative period has been shown to be an effective measure by decreasing the incidence of PU [5]. Likewise, studies have been carried out that show favorable results in the intraoperative setting.

In 1998, Nixon and collaborators., [6] conducted a randomized, double-blind controlled trial in which they compared the use of a viscoelastic polymer pad against a standard operating table mattress for the prevention of PU in the intraoperative with 446 patients undergoing major surgery, finding that the use of this polymer favors the prevention of the development of ulcers in the postoperative period in half of the patients. On the other hand, in 1999, Schultz and collaborators., [38] developed an experimental study on etiology and evaluation of a mattress overlay for use in the operating room to prevent PU during surgeries. To carry out the study, patients were randomly selected into two groups, the first consisting of 207 patients who would receive the usual perioperative care and the second group consisting of 206 patients using a mattress. The authors concluded that although the random process and methods worked correctly, the mattress overlay proved not to be effective for use as an alternative to prevent the development of intraoperative PU.

In a retrospective study in 2006, Sewchunk and collaborators [39] studied the effectiveness of pressure redistribution fluid mattresses in patients undergoing cardiac surgery comparing them against conventional operating mattresses. Likewise, a third arm was created in which, together with the use of fluid mattresses, special postoperative care was added, granted by the nursing department. Each group consisted of 50 individuals, with a total study sample of 150 adult patients. The result favors the use of the tested fluid mattress; however, no statistical analysis of that small difference was performed.

Even though there have been several studies conducted in the field, in terms of prevention in the intraoperative setting, more evidence is needed to justify the intraoperative use of such pressure redistribution surfaces [37]. Despite the development of these devices, it must be taken into account that other clinical factors may also influence the development of PU [40]. Without forgetting that the development of these devices requires the design of robust clinical trials to assess their efficacy and safety, in addition to their cost/benefit analysis [31].

Complications

Some of the most common PU complications are bacteremia, squamous cell carcinoma (0.05%), osteomyelitis (33%), diarthrosis, and sepsis [40]. In addition to the development of these pathologies, patients have an emotional and physical impact. They are subject to pain, additional treatment, and increased days of hospital stay [31].

Graves et al., [40] conducted a study on 2000 patients during the years 2002- 2003 and described that patients with PU had an average of 4.3 days longer than expected for their medical discharge.

Discussion

PU is a recurrent problem of public health and, therefore, it becomes necessary to redouble efforts to reduce its intraoperative incidence. Even though some contributions have been made to technological development in PU prevention measures, it is important to emphasize that there is insufficient evidence. However, literature shows that there are still many challenges that need to

be accomplished for the development of technological devices for the prevention of intraoperative PU. Therefore, it is a priority and a great opportunity to increase the number of studies that assess the efficacy of sensing devices that allow monitoring the risk conditions in the patient during the intraoperative period, such as temperature, humidity, and body weight distribution.

Conclusiones

In conclusion, we reviewed the main technological advances in the prevention of intraoperative PU. The emerging technological alternatives applied to PU prevention promise to translate into better results in the surgical field, but there exists a lack of device studies that show sufficient and effective results; it is still not possible to conclude that current technological advances are definitive solution. We determine that no single concrete and effective solution exists nowadays that encompasses the technology for the definitive prevention of PU.

Acknowledgements: No.

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