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Reconstructive

Hydrosurgical Debridement Allows Effective Wound Bed Preparation of Pressure Injuries: A Prospective Case Series

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Background: Pressure injuries (PIs) are common in hospitalized patients, with incidence exceeding 50% in high-risk patients. Immobilization causes a prolonged compression of vascular networks in tissues overlying bony prominences, leading to ischemia and ulceration. Traditionally, PIs are treated with a combination of surgical debridement and reconstruction. This approach can be invasive for debilitated patients who cannot tolerate prolonged surgeries and extensive tissue resection. Hydrosurgery uses high-pressure irrigation to low-invasively debride and cleanse wounds; its use has shown positive outcomes in burn and chronic wounds care. Here, we hypothesize that hydrosurgery allows low-invasive yet effective wound bed preparation in truncal PIs.

Methods: We conducted a single-center, prospective, uncontrolled case series. Inclusion criteria for this study were presence of a truncal PI (stage III or IV) and an American Society of Anesthesiologists physical status of ≥2 (no exclusion criteria). Measured outcomes included duration of hydrosurgery, postsurgical local (dehiscence, infection, seroma) or systemic complications in the first 30 days, and PI recurrence rate (6-month follow-up).

Results: Seven patients (3 sacral, 2 greater trochanteric, and 2 ischial tuberosity PIs) were enrolled for this study. Average duration of hydrosurgery was 12 minutes (±3.1). No local or systemic complications were observed at a 30-day follow-up (0/7, 0%). All flaps (6/7, 86%) and graft (1/7, 14%) reconstructions successfully survived, and no PI recurrence was reported within a 6-month follow-up (0/7, 0%).

Conclusions: Hydrosurgery seems to allow safe, low-invasive, and effective wound bed preparation in truncal PIs. Larger controlled trials are needed to confirm this preliminary evidence, to guide its broader adoption for improved care of high-risk patients with PIs. *(Plast Reconstr Surg Glob Open 2020;8:e2921; doi: 10.1097/GOX.0000000000002921; Published online 25 June 2020.)*

INTRODUCTION

Pressure injuries (PIs) are among the most common complications observed in hospitalized patients. In the United States alone, over 3 million patients are treated for a PI every year, and similar numbers are globally observed in healthcare systems with both high and limited resources.[1,2] Development and inadequate management of a PI have been associated with a higher patient morbidity, lower quality of life, higher mortality (>2 times higher), prolonged hospitalization (>3 times longer), increased use of medical resources, and substantially increased medical costs (>$18 billion annually in the United States).[3,4] Overall, the impact of PIs on both patients and healthcare systems is massive. This problem is further exacerbated in high-risk and critically ill patients, such as the elderly, those with spinal cord injuries, or those admitted to intensive care units: in these patients, PIs have been reported with an incidence rate over 55%.[1,5] These data highlight

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the critical need for effective management (and prevention) of PIs.

Traditionally, surgical care of PIs in truncal locations overlying bony prominences and with higher concentration of body weight (ischial, sacral, and greater trochanter regions) has involved a 2-stage strategy. This combines the surgical removal of necrotic and fibrotic calcified soft tissue ("bursa": might include cutaneous, subcutaneous, and muscle tissue), lining the wound cavity and with the presence bacteria, and surgical repair by vascularized (flap) or nonvascularized (graft) tissue (cutaneous, fasciocutaneous, muscle, or myocutaneous) transfer. Ink can be used to mark the bursa and to facilitate complete surgical removal of the bursa (Fig. 1A–D).[6–8] Although effective, bursa removal ("bursectomy") is inefficient and imprecise. It commonly involves excessive removal of the tissue (and the unnecessary removal of healthy tissue), it can be technically challenging in more superficial portions of the bursa, and it requires substantial surgical time and efforts.[9] These limitations are particularly relevant for debilitated, high-risk patients in whom prolonged or more invasive surgeries can significantly affect postoperative morbidity, mortality, and length of hospitalization.[10,11]

Other strategies and techniques for wound debridement have been developed and studied. In particular, hydrosurgery is a technique that uses high-pressure saline irrigation to debride and cleanse tissues combined with simultaneous aspiration of necrotic debris.[12] Over the past 15 years, it has been successfully used for the management of second-degree burns,[13,14] diabetic ulcers,[15] and wounds requiring repair by skin grafts.[16] Collectively, hydrosurgery has been shown to be equally effective for surgical debridement while being less invasive. Despite the obvious clinical potential of its application in the management of PIs in high-risk patients, only sparse anecdotal cases have been reported on the topic.

Here, we aim to further strengthen the evidence on the application of hydrosurgical wound bed preparation in PI care with the overarching goal of improving best surgical practice for these patients. We hypothesize that hydrosurgery allows low-invasive (short wound bed preparation time, low complication rate) yet effective (high success rate of reconstruction, low recurrence rate) wound bed preparation in truncal PIs.

METHODS

Study Design

We designed a single-center, single-surgeon, prospective, uncontrolled case series. The study complied with the principles outlined in the Declaration of Helsinki. All subjects gave their written informed consent for the procedures described in this study and for the release of the photographs included in this study.

Inclusion criteria for the study were the presence of a truncal PI requiring debridement and surgical repair (stage III or IV based on the National Pressure Ulcer Advisory Panel classification) and an American Society of Anesthesiologists physical status (ASA-PS) ≥2; there were no absolute or relative exclusion criteria.

Wound Preparation

The eschar and the subcutaneous necrotic tissue were preliminarily removed using an electric scalpel without anesthesia. Before surgery, PIs were treated with daily saline irrigation or by negative pressure wound therapy (NPWT) (70 mm Hg continuous suction; RENASYS; Smith & Nephew Wound Management, London, United Kingdom) for a week. Preoperatively, the PI (PI surface area, bursa volume) was measured using digital imaging, and swabs were obtained for assessment of the presence of bacteria. If pathogens were identified at swab culture, antibiotic therapy was administered by endovenous infusion up to 1 week after the reconstructive surgery; the choice of the agent was based on the antibiotic susceptibility.

Hydrosurgical Wound Bed Preparation

Methylene blue was used to mark the entire surface of the bursa and to guide debridement.[8] Under general anesthesia, a limited incision was made in the bursa to resect the marginal scar. Hydrosurgery (VERSAJET II; Smith & Nephew, Watford, United Kingdom) was then used to remove necrotic tissue while preserving granulation tissue and to ensure punctate hemorrhage on the wound bed. All procedures were carried out by the same surgeon. Achievement of an adequate wound bed preparation was confirmed clinically. The duration of hydrosurgery was recorded.

Bone protrusions were resected or smoothened as minimally as possible. Healthy overlying skin was preserved to facilitate wound closure.

Surgical Reconstruction

Fasciocutaneous flaps or split-thickness (12/1000 inch) skin grafts were used to repair soft tissue defects. Decision-making was based on the quality of the skin overlying the bursa. If the skin was considered sufficiently vascularized and reliable, a split-thickness skin graft harvested from the right thigh region was used. Instead, if the skin appeared markedly thin after debridement, a pedicled fasciocutaneous flap was raised, partially de-epithelialized, and inserted into the bursa as a cushion. The skin paddle of the de-epithelialized fasciocutaneous flap was appropriately anchored by suturing it to the internal wall to ensure that it completely filled the subcutaneous bursa cavity. Surgical drains were applied and maintained until the absence of collected fluids from the surgical site.

Weight bearing on the reconstruction side was restricted for 2 weeks postoperatively (patients were kept in a supine or lateral decubitus position to avoid bearing weight over the flap site, as previous literature suggests), and a pressure-relieving mattress was used during recovery.[17] These mattresses are specifically designed to dynamically reduce a prolonged pressure on specific body areas. Dressing changes were performed daily; at the same time, swabs for bacterial culture and monitoring were collected.

Follow-up and Measured Outcomes

Postoperative follow-up occurred daily during hospitalization, then weekly until postoperative day 30, and then monthly until postoperative month 6. Postoperative outcomes were measured clinically and with wound swabs

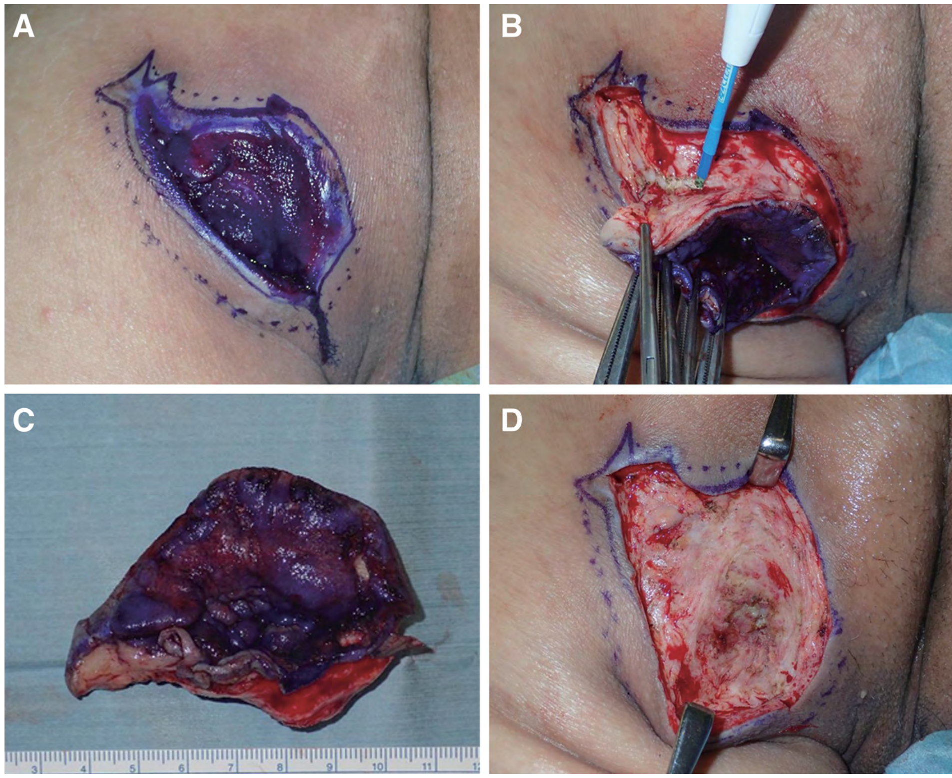

Fig. 1. Example of bursectomy. A, Bursa cavity stained with gentian violet. B, Resected bursa specimen. C, Wound after bursectomy. D, Resected bursa.

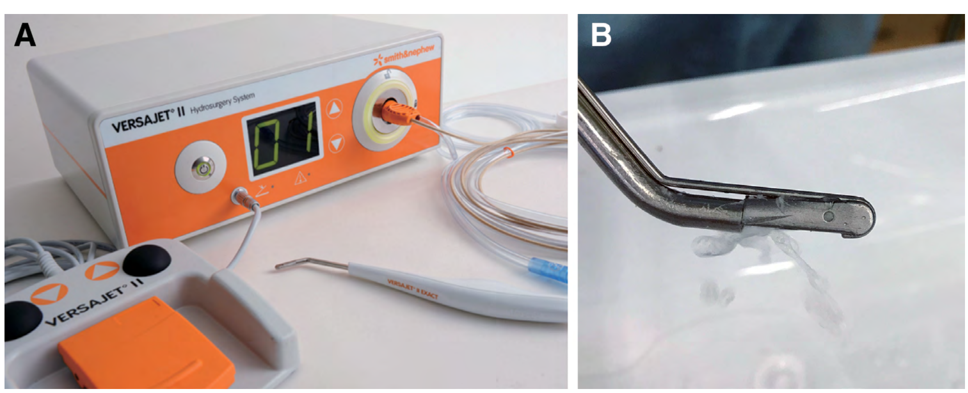

Fig. 2. Hydrosurgery system (VERSAJET II). A, Body of the device. B, Hand piece for irrigation and simultaneous aspiration.

(per our Institutional guidelines, although these might be more inaccurate than tissue biopsies), and these outcomes included local complications (wound dehiscence, surgical site infection, wound seroma) and systemic complications related to the PI in the first 30 days and PI recurrence rate within the 6-month follow-up.

RESULTS

Patients' Characteristics

We treated 7 patients [4 men, 3 women; mean age, 78.9 years (62–90)]. Average preoperative serum albumin level was 2.8 mg/dL (±0.4).

The locations of PIs were the sacral region (3 patients), the greater trochanter region (2 patients), and the ischial tuberosity (2 patients); 1 patient had a stage III PI, while 6 patients had a stage IV PI. The mean skin ulcer area was 26.4 (4–88) cm^2, with a mean bursa size of 53 (21–79) cm^2 (Table 1).

Preoperative wound culture showed bacterial presence in the wound in 6 of 7 patients: details on detected pathogens and adopted antibiotic therapies are provided in Table 1. Preoperative NPWT was applied to 5/7 (71%) patients. A fasciocutaneous flap was used for reconstruction in 6 patients, while a split-thickness skin graft was used in 1 patient (Table 1).

Table 1. Clinical Cases

Case No.	Sex	Age	Primary Disease	ASA-PS	Albumin Level, g/dL	Location of PI	Skin Ulcer, cm²	Bursa Size, cm²	NPUAP Pressure Ulcer Classification	Preoperative NPWT	Duration of Hydrosurgery, min	Reconstructive Procedure	Duration of Drains, d	Bacterial Presence
1	F	62	Multiple sclerosis	3	3.1	Right ischial tuberosity	6	71	Stage IV	Yes	15	Posterior thigh flap	7	1. *Enterobacter cloacae* 2. *Enterobacter aerogenes*
2	M	87	Hypertension	2	3.1	Sacrococcygeal region	88	62	Stage IV	Yes	10	Rotation flap	7	None
3	F	90	Hypertension, Diabetes	2	2.3	Right greater trochanter	50	50	Stage IV	Yes	15	TFL flap	7	*Klebsiella oxytoca*
4	M	76	Spinal cord infarction	3	3.1	Sacrococcygeal region	18	66	Stage IV	Yes	14	Rotation flap	7	MRSA
5	M	88	Hypertension	2	2.9	Left greater trochanter	4	21	Stage IV	No	7	TFL flap	7	CNS
6	F	81	Diabetes	2	2.6	Sacrococcygeal region	9	79	Stage IV	Yes	13	Rotation flap	7	*Pseudomonas aeruginosa*
7	M	69	Diabetes	2	2.3	Right ischial tuberosity	10	22	Stage III	No	10	STSG	N/A	MSSA

CNS, coagulase-negative staphylococci; F, female; M, male; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*; NPUAP, National Pressure Ulcer Advisory Panel; NPWT, negative pressure wound therapy; PI, pressure injury; STSG, split-thickness skin graft; TFL, tensor fasciae latae.

Hydrosurgery Provides Effective Wound Bed Preparation in Truncal PIs

The average time to perform hydrosurgical wound bed preparation was 12 minutes (±3.1). All surgeries were successful with complete survival of both flaps and skin grafts. No recurrence of PIs was recorded within the 6-month follow-up.

Hydrosurgical Wound Bed Preparation of Truncal PIs Is Safe

We did not observe any local (wound dehiscence, flap/graft necrosis, surgical site infection, or wound seroma) or systemic complications in patients within the first 30 days postoperatively. Postoperative wound swabs were negative for bacterial presence in all patients. All surgical drains were maintained for 7 days.

Selected Cases

Patient 1

The patient was a 62-year-old woman with a history of multiple sclerosis who had been using a wheelchair for several years (ASA-PS, 3) and who had developed a stage IV PI over the right ischial tuberosity (Fig. 3A). After NPWT and wound preparation, we proceeded

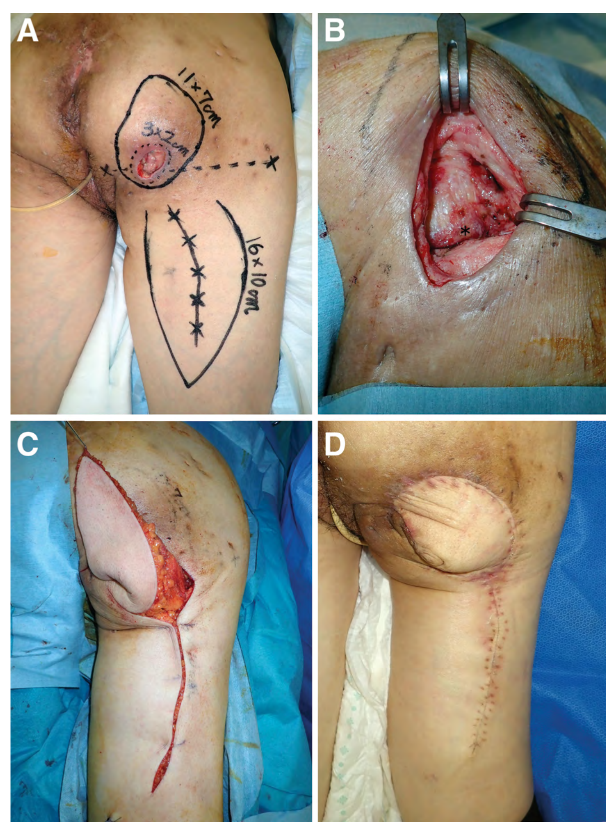

Fig. 3. Case 1: a 62-year-old woman with a PI over the right tuberosity. A, Preoperative photograph showing the PI with an area of 6 cm²; the volume of the subcutaneous bursa was 71 cm². B, Wound bed preparation by hydrosurgery. Since the ischial tuberosity (*) was protruding into the PI, we performed a conservative resection of exposed bony tissue. C, Rotation and positioning of the posterior thigh flap (16 × 10 cm²). D, Tissue defect repaired at 30 days postoperatively.

with wound bed preparation by hydrosurgery (Fig. 3B) (**see Video [online]**, which displays hydrosurgical debridement of truncal pressure injury for wound bed preparation). The procedure took 15 minutes. Since the ischial tuberosity protruded into the PI, we performed a conservative resection of the exposed bone tissues.

For reconstruction, a 16 × 10-cm posterior thigh flap was obtained from the area below the quadriceps muscle fascia. The flap was transposed by 180 degrees to completely fill the tissue defect over the ischial tuberosity, and the wound was closed (Fig. 3C).

Postoperatively, no local or systemic complications were observed (Fig. 3D), and no PI recurrence was reported in the first 6 months after surgery.

Patient 2

The patient was an 87-year-old man who had been bedridden for over 5 years (ASA-PS, 2) and had developed a stage IV PI over the sacrococcygeal region (Fig. 4A). Wound swabs confirmed that the wound had no bacteria. The patient received preoperative NPWT.

We first resected the marginal scar of the PI, then we used the hydrosurgery system to debride the surface of the bursa (Fig. 4B). The procedure took 10 minutes. Since the sacrum was protruding into the PI, we performed a conservative resection of exposed bone tissues.

We then designed 2 fasciocutaneous rotational flaps harvested from the gluteal regions bilaterally and used them to reconstruct the tissue defect (Fig. 4C). Postoperatively, no local or systemic complications were observed (Fig. 4D), and no PI recurrence was reported in the first 6 months after surgery.

Patient 3

The patient was a 90-year-old woman (ASA-PS, 2) who had an accidental fall after losing consciousness and lay in a right recumbent position until she was rescued, which led to the development of a stage IV PI over the right greater trochanter (Fig. 5A).

After NPWT and wound preparation, we proceeded with hydrosurgical wound bed preparation (Fig. 5B). The procedure took 15 minutes.

Once adequate bed preparation had been achieved, we raised a 20 × 12-cm tensor fasciae latae flap and used it to fill the tissue defect in the right greater trochanter region, before final wound closure (Fig. 5C).

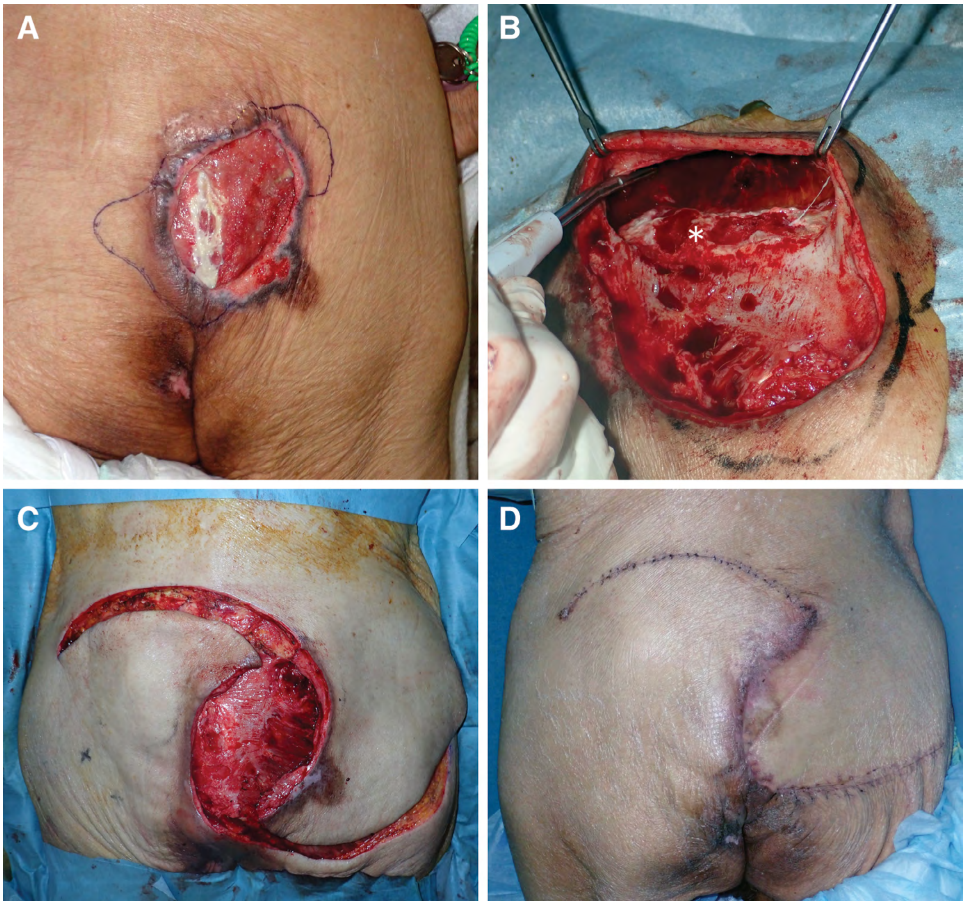

Fig. 4. Case 2: an 87-year-old man with a PI over the sacrococcygeal region. A, Preoperative photograph showing the PI with an area of 88 cm^2; the volume of the subcutaneous bursa was 62 cm^2. B, Wound bed preparation by hydrosurgery. Since the sacrum (*) was protruding into the PI, we performed a conservative resection of exposed bone tissue. C, Two fasciocutaneous rotational flaps from bilateral gluteal regions were designed and raised. D, Tissue defect repaired at 30 days postoperatively.

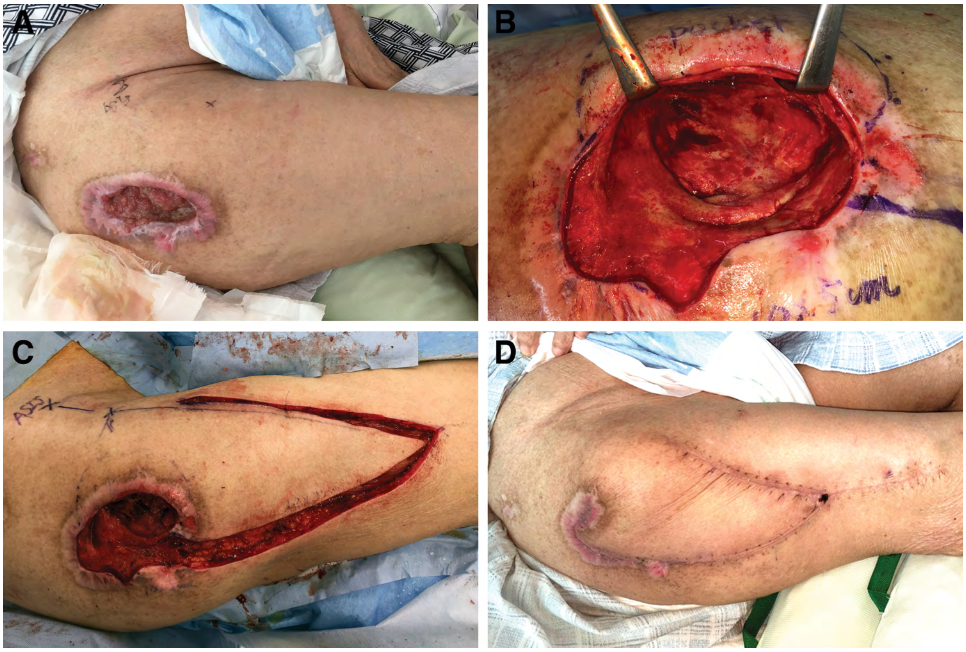

Fig. 5. Case 3: a 90-year-old woman with a PI over the right greater trochanter. A, The preoperative findings show the PI with an area of 50 cm^2; the volume of the subcutaneous bursa was 50 cm^2. B, Wound bed preparation by hydrosurgery. C, Design and elevation of the tensor fasciae latae flap (20 × 12 cm^2). D, Tissue defect repaired at 30 days postoperatively.

Postoperatively, no local or systemic complications were observed (Fig. 5D), and no PI recurrence was reported in the first 6 months after surgery.

DISCUSSION

In this study, we show that hydrosurgery can provide a safe wound bed preparation alternative to surgical debridement (bursectomy) in high-risk patients with PI requiring a surgical repair. Using this protocol, surgical care of patients was effective (100% success).

Hydrosurgery time was kept under 15 minutes, no perioperative or postoperative complications were observed, all cases with preoperative bacterial presence showed negative postoperative wound swabs, and no PI recurrence was recorded within 6 months of the surgery.

PI are extremely common and extremely dangerous complications in frail patients such as the elderly and in those who are critically ill, posing a substantial burden also on healthcare systems and societies.[1,18] Beside their direct impact on patients' quality of life and well-being, PI commonly prolong patients' hospitalization, is associated with life-threatening complications, and increases patients' mortality.[3]

Despite the critical need for effective surgical managements of PIs, surgical repair has been associated with a relatively high rate of complications, failures, and recurrences.[4–11] Literature reports (major and minor) failure rates of surgical flap repair as high as 20%,[19] and postoperative complication (dehiscence, seroma or hematoma formation, surgical site infection) rates of 15%–30% of cases.[20,21] Consistently, postsurgical recurrence has been shown to affect >20% of treated PIs.[22,23]

These poor outcomes are often attributed, at least in part, to the debilitated conditions of patients and to an inadequate wound debridement.[24] Importantly, today there is no Level I evidence to support any specific method of debridement (including bursectomies) over another.[1,25–27] We believe that the adoption of less invasive, yet equally effective, therapeutic approaches has the potential to maximize tissue and patient response to treatment while minimizing deleterious local and systemic impact on healing processes.

In this light, wound bed preparation by hydrosurgery can offer a practical alternative to standard surgical debridement (bursectomy). Surgical access required for hydrosurgery is minimal (often a small incision in the bursa). Proper use of hydrosurgery allows selective debridement of necrotic tissue with preservation of healthy tissue, improving the quality of wound beds receiving flaps/grafts.[28] This selective debridement could contribute to the lowered risk of infection, further supporting healing.[29] In our experience, hydrosurgery is more easily performed on soft necrotic tissues (including fat) than on hard necrotic tissues (eg, tendons and periosteum). In trained hands, hydrosurgery also reduces operative time for patients.

Our results seem to support the hypotheses above and the effectiveness of the approach in comparison to the methods previously reported in literature. They are also consistent with previous reports on the use of hydrosurgery in the management of other types of wounds. Limited reports have described using hydrosurgery in the management of sparse cases of PIs:[15,30] to our knowledge this is the largest case series to assess these outcomes in a more controlled and detailed setting, and to propose a novel integrated therapeutic and operative approach involving three consecutive stages. There are no relative or absolute contra-indications to hydrosurgery; in extremely severe patients unable to tolerate surgery, enzymatic debridement with conservative/palliative wound care could be preferred.

This study has some limitations. It is a small, uncontrolled, case series with no formal comparison to standard of care (bursectomy). Specifically, it does not provide higher-level evidence that the debridement is specifically or solely associated with observed positive outcomes. Yet, in this series of representative patients, we observed no complications nor recurrences but a 100% success of surgical repair. These outcomes are superior to those previously reported. Since the rest of our treatment protocol is consistent with standard of care, we postulate that at least a part of the benefit observed relates to the use of hydrosurgery. Similarly, our preliminary experience does not allow the proposal of formal therapeutic algorithm and specific indications for preference of hydrosurgery of surgical debridement in PI management. We did not include an analysis of costs (hydrosurgery systems and require disposable components) or cost-effectiveness of the strategy. In addition, a certain degree of experience is required to ascertain the extent and depth of debridement, and scrupulous hemostasis is needed after debridement. Future studies will help address and provide an answer to these important aspects.

CONCLUSIONS

Hydrosurgery seems to allow safe (low rate of local or systemic complications), low-invasive (duration <15 minutes), and effective (high rate of surgical success, low rate of recurrence rate at 6 months) wound bed preparation of truncal PIs. Given the limitations of this study, we advise that conclusions should be pondered with caution. Larger controlled trials are needed to confirm this preliminary evidence and guide broader adoption of this strategy for the improved surgical care of high-risk patients with PIs.

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PATIENT CONSENT

Patients provided written consent for the use of their images.

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