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ORIGINAL ARTICLE

Negative pressure wound therapy in acute, contaminated wounds: documenting its safety and efficacy to support current global practice

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Abstract

Negative pressure wound therapy (NPWT) is in widespread use and its role in wound care is expanding worldwide. It is estimated that 300 million acute wounds are treated globally each year. Currently, sporadic data exist to support NPWT in acutely contaminated wounds. Despite lack of data, use of negative pressure wound therapy in such cases is increasing across the globe. We retrospectively reviewed 86 consecutive patients, totalling 97 contaminated wounds. All wounds were Class IV based on US Center for Disease Control criteria. Sepsis criteria were present in 78/86 (91%) of patients. All patients were managed with NPWT. Wound type, degree of tissue destruction, presence of infection, wound dimension, timing of initial NPWT, type and timing of wound closure and patient comorbidities were recorded. Outcome endpoints included durability of wound closure and death. Wound location was 41/97 (42%) in the torso; 56/97 (58%) at the extremities. Tissue necrosis was present in 84/97 (87%) of wounds. Infection was present in 86/97 (89%) of wounds. Average wound size was 619 cm^2 when square surface area measured; 786 cm^3 when volume measurements taken. Mean time to wound closure was 17 days, median 10 days and mode 6 days. Durability of wound closure 73/79 (92%). Deaths were noted in 6/86 (7%) of patients. No deaths appeared related to NPWT. Contemporary NPWT related acute wound care is expanding empirically, in quantity and scope across the globe. However, several areas of concern are known regarding this contemporary use of NPWT in acute wounds. Thus, it is important to assess the safety and efficacy of such expanded empiric NPWT practice. Based on our findings with NPWT in the largest known patient cohort of this type, NPWT appears safe and effective in managing acute, contaminated wounds including patients meeting sepsis criteria. These findings provide evidence-based support for current worldwide empiric NPWT-related acute wound care.

Introduction

Negative pressure wound therapy (NPWT) came into widespread use in 1997 after the publication of a subatmospheric wound care technique (1). Foam or gauze is placed into the wound which is then covered by a plastic drape and the system set to suction via tubing. The Vacuum Assisted Closure (V.A.C.®) device [Kinetic Concepts Inc. (KCI), San Antonio, TX], is the most widely available commercial product, though at least nine proprietary products exist worldwide (2,3).

Key Messages

- with a lack of clearly defined outcome data for NPWT in acute wound care, but with a rapidly expanding, but empiric global practice occurring, the aim of this study

was to assess the safety and efficacy of NPWT, used in a consecutive series of patients with acute, contaminated wounds
- importantly, the patient cohort in this study mirrors currently expanded, worldwide, empiric NPWT acute wound care
- specifically, the wounds in this patient cohort were all contaminated and of large dimension, and thus analogous to wounds from war injuries, terrorism, natural disasters and the environment of 'least developed countries'
- extrapolating the results of this study can guide assessments of the safety and efficacy of empirically expanding worldwide practices of NPWT in acute wound care
- FDA indications for NPWT are 'chronic, acute, traumatic, subacute and dehisced wounds, partial-thickness burns, ulcers (such as diabetic or pressure), flaps and grafts'
- several areas of concern arise in the contemporary use of NPWT in acute wounds but there is limited published literature of NPWT in such cases
- NPWT in the Third World is expanding, proposed as being of 'great value in treating severe wounds in underdeveloped countries'
- however, lack of resources for comprehensive acute wound care, lack of sterile supplies, loss to follow-up and lack of published data in this setting are noteworthy
- the wound cohort in this study mirrors current empiric, global acute wound NPWT practice
- limitations to our study include the lack of a control group; yet, publications to date reflect the inherent difficulty of prospective, randomised trials in wound care
- from a patient focused care perspective, there were practical needs to apply NPWT as opposed to non NPWT care in this patient cohort
- based on our findings with NPWT in the largest known patient cohort of this type, NPWT appears safe and effective in managing acute, contaminated wounds including patients meeting sepsis criteria

NPWT in wound care is in wide clinical use. Over 338 million V.A.C.® therapy days are reported worldwide during a 2-year period, 2009–2011, (c/o Steve Jackson/KCI, telephone conversation 7/1/2011). Yet the exact mechanisms of action of NPWT in wound healing are yet to be fully elucidated (3). Evidence to date supports four main processes: decreasing oedema results in lessened tissue pressure and improved capillary perfusion; increasing vascularity enhances oxygenation and nutrient delivery; removing wound area inflammatory proteases and cytokines causes favourable alterations in the biochemical cascade; and mechanical wound deformation causes tissue strain and resultant cellular proliferation (2–5).

To date, nine randomised control trials (RCT) of NPWT in wound care exist ($n = 429$); however, the methodological quality of these studies is questioned because of varied outcome definitions and endpoints (3,6–14). Several studies note surrogate wound closure variables of decreased wound dimension and/or presence of granulation tissue, rather than complete wound closure itself (8–10). The US Food and Drug Administration (FDA) notes the latter as 'the most clinically meaningful' wound endpoint and states that 'the clinical benefit of incremental wound size changes has not been established' (15). Of note, only 3/7 of the RCT studies reported a significantly faster time to complete wound closure, development of granulation tissue or reduction in wound surface area (8,9,11). Hence, evidence-based conclusions relating to wound closure endpoints are lacking regarding the clear benefit of NPWT compared to contemporary non NPWT wound care.

Despite the lack of evidence-based data relating to wound closure, NPWT continues to grow into an integral part of current empiric wound care practice. Total revenues for KCI were 700 million dollars (US) in 2004, increasing to 2·02 billion dollars (US) in 2010 (3,16). The amplified use is probably because of the documented (but non wound closure related) benefits of NPWT. These include ease of use, patient comfort via decreased dressing changes, control of wounds with increased secretions, and facilitated outpatient care (2,6,17,18). In addition, the empiric use of NPWT in complex wounds is increasingly reported as related to military conflicts (e.g. wars in Iraq and Afghanistan), terrorist attacks (e.g. 2005 London Underground Transport Network bombing) and natural disasters (e.g. 2005 Southeast Asia tsunami) (19–23). Furthermore, a specific benefit of NPWT in transporting patients with complex acute traumatic war wounds is reported and undergoing formal investigation by the US military (22).

Not surprisingly, with the increased use of NPWT in the industrialised world, acceptance of this technique in 'least developed countries' (as defined by the United Nations based on socio-economic criteria) is occurring, as well (7,24). However, lack of resources for sterile supplies and lack of comprehensive wound management in these settings raises reasonable concern about the growing empiric use of NPWT in such acute wound care.

With a lack of clearly defined outcome data for NPWT in acute wound care, but with a rapidly expanding, but empiric global practice occurring, the aim of this study was to assess the safety and efficacy of NPWT, used in a consecutive series of patients with acute, contaminated wounds. Importantly, the patient cohort in this study mirrors currently expanded, worldwide, empiric NPWT acute wound care. Specifically, the wounds in this patient cohort were all contaminated and of large dimension, and thus analogous to wounds from war injuries, terrorism, natural disasters and the environment of 'least developed countries'.

Of note, the vast majority of patients in this cohort meeting sepsis criteria define the acuity of these wounds; and it corroborates the patient cohort being evaluated. Extrapolating the results of this study can guide assessments of the safety and efficacy of empirically expanding worldwide practices of NPWT in acute wound care.

Methods

Study population

Acute wounds created ≤24 hours prior to, or subsequent to the time of hospital admission, and requiring surgical intervention. Wound aetiologies were traumatic, infectious, or post surgical (Table 1). Presence of wound contamination was required (e.g. tissue necrosis and/or infection). Thus, all wounds were Class IV based on US Center for Disease Control (CDC) criteria (25). 'Open abdomen' wounds, that is, defects below the level of the midline fascia were excluded.

Databases

A single institution, single surgeon's records were used for data collection. This methodology limited variables in wound care management. Inpatient and outpatient records were reviewed.

Wound care strategy

Indications for surgery followed practice standards of care. History, physical examination, laboratory and radiographic data were utilised in decision making. Evidence or concern for tissue necrosis, presence or concern for undrained and infected fluid (and not amenable/appropriate to lesser invasive approaches) and presence or concern for spreading/necrotising soft tissue infection prompted surgical intervention.

Surgical care was provided in the operating room under general anaesthesia or monitored anaesthesia care (MAC). Intraoperative care involved sharp, blunt and/or hydromechanical (Versajet™; Smith and Nephew, St. Petersburg, FL) resection of all grossly necrotic tissue. Complete evacuation of infected fluid was done. Intra-operative pulse irrigation (InterPulse Powered Lavage System; Stryker, Kalamazoo, MI) was used in all cases except for one case involving the epidural space. Intra-operative cultures (swab and/or tissue) were taken in cases where there was concern for deep space infection, spreading soft tissue infection, or resistant organisms.

Negative pressure wound therapy via the V.A.C.® system was used in all wounds except the few cases where cross-covering physicians were involved (7/97 wounds). A gauze-based negative pressure wound therapy was applied in these select cases, with a V.A.C.® instituted, or wound closure done thereafter.

All patients with concern for infection were treated with antibiotics. Specialists in infectious disease were utilised where resistant microbial organisms and/or osteomyelitis were involved.

The above wound care strategies were effected in similar fashion in each case. Care was provided predominantly by a single surgeon Board-certified in General Surgery and Surgical Critical Care. Cross coverage was provided by a limited number of partnering surgeons.

Study design

This was a retrospective chart review of a consecutive series of patients between August 2004 and April 2011. A single institution and single surgeon's data set were involved. This methodology limited variables in wound care management. Study criteria were applied in assessing contiguous wound cases. Informed consent for surgery and the use of negative pressure wound therapy was obtained in all cases. Informed consent was obtained from patients or surrogates (if patient capacity was an issue). The study design was reviewed and accepted by the Christiana Care Health System's Institutional Review Board.

Results

Wound location

Wounds involving the extremities, defined as distal to the axilla or inguinal crease, were present in 41/97 (42%). Wounds involving the torso, head and neck were 56/97 (58%). (Because of contiguity, two wounds involved a combination of extremity and torso locations.)

Degree of tissue destruction and/or infection

Tissue necrosis was present in 84/97 (87%) of wounds. Depth of necrosis within skin only was present in 0/84 wounds; skin and subcutaneous tissue in 13/84 wounds; skin, subcutaneous tissue and fascia in 38/84 wounds; skin, subcutaneous tissue, fascia and muscle in 21/84 wounds; and skin, subcutaneous tissue, fascia, muscle and bone in 8/84 wounds. Necrosis within muscle only (i.e. myositis) was present in 3/84 wounds.

Traumatic amputations from an inciting event were involved in 5/41 wounds. Subsequent amputation because of irrecoverable tissue loss and/or infection occurred in 3/41 extremity wounds. (Of these 1/3 did not have NPWT applied at initial presentation but rather after the amputation was effected on hospital day 4; and 2/3, based on concurring opinions at the time of initial evaluation (pre-NPWT), were anticipated to need future amputation. Thus, precipitation of amputation from the use of NPWT seems unlikely). Refractory osteomyelitis was present in 1/41 wounds, but the patient declined a recommended amputation and was lost in follow-up. Loss of function of the lower extremity was noted in 1/41 wounds, and amputation recommended, but the patient refused and was also lost in follow-up. Overall 10/41 (24%) of extremity wounds involved an amputation or advisement thereof.

Infection was present in 86/97 (89%) of wounds. This was confirmed by wound purulence and/or cultures in 83/86 (97%). In order to standardise and compare initial wound assessments, cultures were reported during the narrow time interval noted (rather than at any time in the patient's hospitalisation). In 2/86 patients, clinical criteria for wound infection were present despite negative initial cultures. However, subsequent cultures were positive, corroborating initial clinical concern. In 1/86 cases, the patient did not have positive cultures, but he improved with evacuation of a clinically suspected infected haematoma and the use of broad-spectrum systemic antibiotics.

Table 1 Patient and wound cohort characteristics with outcomes

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#1	72	M	L calf necrotizing soft tissue infection & myositis	Necrosis of muscle	Infection	Class IV, Severe Sepsis	1080 cm^3	T-1	3 days bedside	pus	Y	Y	Y	N	Y	27 days	DPC	Myelodysplastic syndrome-steroid dependent, thrombocytopenia, CAD, HTN, DM, Morbid obesity: BMI = 40		Death HD36[1]
#2	48	M	LLE (iliac crest to ankle) degloving injuries w/ soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Trauma	Class IV, Septic Shock	4000 cm^2	T-0 Modified NPWT; subsequent NPWT	7 days	pus	Y	Y	N	Y	NT	48 days	STSG	CHF, DM, Morbid obesity: BMI = 52, Smoker, DVT, Lymphedema		
#3	59	M	L thigh & foot degloving injuries & subsequent necrotizing soft tissue infection requiring BKA	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone	Trauma	Class IV, Sepsis	950 cm^2	T-1	4 days	pus	Y	Y	Y	Y	Y	25 days	STSG	HTN		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#4	62	M	Fournier's gangrene	Necrosis of skin, subcutaneous tissue, & fascia w/ perirectal abscess	Infection	Class IV, Sepsis	100 cm^2	T-0	3 days		Y	N	N	Y	Y	16 days	DPC	HTN, DM	Wound dehisced on POD8 S/P initial DPC. Re-exploration & same day DPC effected.	
#5	38	F	Abd wall necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Sepsis	750 cm^2	T-0	2 days	pus	Y	Y	N	Y	Y	2 days	DPC	Obesity: BMI = 37,		
#6	79	F	L calf necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue; & cellulitis	Infection	Class IV, Sepsis	180 cm^2	T-1	3 days		Y	Y	N	Y	N	52 days	STSG + NPWT	CHF, Afib, HTN, Pulm HTN, ARF, Rhabdomyolysis		
#7	47	F	L thigh & gluteus muscle soft tissue infection	Deep space abscess	Infection	Class IV, Sepsis	75 cm^2	T-0	3 days	pus	Y	Y	N	Y	Y	6 days	DPC	Uterine CA, HTN, DM, Obesity: BMI = 34		
#8	55	F	Interscapular necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Sepsis	121 cm^2	T-0	2 days	pus	Y	Y	Y	Y	Y	excluded due to secondary intention closure	Secondary Intention	HTN, Obesity: BMI = 37		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#9	49	M	Fournier's gangrene	Necrosis of skin, subcutaneous tissue, fascia, & L testicle	Infection	Class IV, Sepsis Shock	240 cm^3	T-1	2 days	pus	Y	Y	N	Y	Y	17 days	DPC	Stage IV CA pharynx, DM, Obesity: BMI = 34, Smoker		
#10	70	M	Interscapular necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia w/deep space abscess	Infection	Class IV, Sepsis	900 cm^3	T-0	3 days	pus	Y	N	N	Y	Y	15 days	DPC	MI, HTN, DM, Smoker		
#11	55	M	L gluteal necrotizing soft tissue infection & Fournier's gangrene	Necrosis of skin, subcutaneous tissue, & fascia w/ deep space abscess	Infection	Class IV, Severe Sepsis	480 cm^3	T-0	2 days	pus	Y	N	N	Y	N	8 days	DPC	HTN, DM, Obesity: BMI = 39, Spinal stenosis		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#12	42	M	BUE Necrotizing soft tissue infection, cellulitis, & pyomyositis	R: necrosis of skin, subcutaneous tissue, fascia, muscle, & bone; L: necrosis of skin, subcutaneous tissue, fascia, & muscle w/ abscess, cellulitis, & pyomyositis	Infection	Class IV, Sepsis	R: 4500 cm^3 L: 500 cm^3	T-0	1 day	pus	Y	N	Y	Y	Y	24 days	DPC	HTN, DM, Obesity: BMI = 30, Recurrent skin infections		
#13	37	F	Abd wall necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia w/multiple subcutaneous abscesses	Infection	Class IV	80 cm^2	T-0	2 days	pus	N	N	N	Y	Y	see out-come	Secondary intention	DM	Purulent drainage 2 days S/P NPWT → Care provided by separate on call physician & NPWT d/c'd	
#14	41	M	L tibia to thigh abscess	Deep seated soft tissue abscess w/ associated myositis & cellulitis	Infection	Class IV, Severe Sepsis	45cm length	T-0	2 days	pus	Y	Y	N	Y	Y	9 days	DPC	ARF		
#15	45	M	L forearm electrical burn w/ necrosis	Necrosis of skin, subcutaneous tissue, & fascia	Trauma	Class IV, Sepsis	72 cm^2	T-0	2 days	pus	Y	N	N	Y	N	6 days	DPC	Smoker		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Puru-lence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complica-tions	Mortality
#16	58	F	L lateral abd wall & retroperi-toneal necrotizing soft tissue infection 2° bowel perf	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Septic Shock	4000 cm^2	T-0 Modified NPWT; subse-quent NPWT	2 days	pus	Y	N	Y	Y	Y	see out-come	Secondary intention	HTN, DM, Morbid obesity: BMI = 71, CRI,TIA's, Lymphedema	Prolonged NPWT & subsequent secondary intention closure over 3 mos.	
#17	47	M	R biceps blunt force injury w/ myo-necrosis	Myonecrosis	Trauma	Class IV, SIRS	300 cm^3	T-0	3 days		N	N	Y	Y	NT	6 days	DPC	Smoker		
#18	42	M	L calf-circum-ferential, necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Trauma	Class IV, Septic Shock	>500 cm^2	T-0	3 days		N	N	Y‡	Y	Y	9 days	DPC + STSG	HTN, DM, Morbid obesity: BMI = 50, ESRD, charcot foot		
#19	23	M	L calf mangled extremity requiring BKA; R calf degloving injury	L necrosis of skin, subcutaneous tissue, fascia, muscle, & complex open tib fib/ankle fxs; R necrosis of skin, subcutaneous tissue, & fascia	Trauma	Class IV, SIRS	L: 100 cm^2 R: 1500 cm^3	T-0	3 days		Y	Y	Y	Y	NT	L: 24 days R: 64 days	L: DPC R: STSG	N/A		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Puru-lence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complica-tions	Mortality
#20	21	M	L hip/ thigh shearing injury, Morel-Lavallee	Necrosis of skin, subcu-taneous tissue, & fascia w/ infected hematoma	Trauma	Class IV, Severe Sepsis	1650 cm^2	T-0	1 day		Y	N	N	Y	NT	6 days	DPC	Obesity: BMI = 33, Asthma		
#21	31	M	L calf mangled extremity requiring BKA	Necrosis of skin, subcu-taneous tissue, fascia, & muscle w/open metatarsal fxs	Trauma	Class IV, Sepsis	200 cm^2	T-0	3 days	pus/ exudate	Y	N	N	Y	Y	17 days	STSG	Obesity: BMI = 31	Recurrent infections @ open BKA site	
#22	47	F	L chest wall/ breast blunt force; open injury requiring mastec-tomy; open R axillary wound	Necrosis of skin, subcu-taneous tissue, & fascia	Trauma	Class IV, SIRS	500 cm^2	T-0	3 days		Y	N	N	Y	NT	10 days	DPC	Obesity: BMI = 39, Smoker		
#23	39	M	L groin/thigh & R ankle necrotizing soft tissue infection	Necrosis of skin, subcu-taneous tissue, & fascia	Infection	Class IV, Septic Shock	L>500 cm^2 R> cm^2	T-1	L: 3 days R: 2 days	dishwater fluid	Y	Y	N	Y	L: Y R: NT	L: 5 days R: 11 days	L: DPC R: STSG	DM, Morbid obesity: BMI = 68, Hep C, Transverse myelitis w/ LLE partial paralysis		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Puru-lence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complica-tions	Mortality
#24	75	M	L ankle & foot necrotizing soft tissue infection requiring BKA	Necrosis of skin, subcu-taneous tissue, fascia, & muscle w/ osteomy-elitis	Infection	Class IV, Septic Shock	100 cm^2	T-0	6 days		Y	N	Y	N	NT	9 days	DPC	Severe aortoiliac occlusive disease MI, CAD, CHF, Afib on coumadin, DM, COPD, ESRD, CVA		
#25	52	F	Fournier's gangrene	Necrosis of skin, subcu-taneous tissue, fascia, & muscle	Infection	Class IV, Septic Shock	750 cm^3	T-0	2 days	pus	Y	N	Y	Y	Y	44 days§	DPC + NPWT	HTN, DM, Morbid obesity: BMI = 52, Malnutrition		
#26	86	M	Fournier's gangrene	Necrosis of skin, subcu-taneous tissue, & fascia w/ perirectal abscess	Infection	Class IV, Septic Shock	270 cm^3	T-2	3 days	pus	Y	N	Y	Y	Y	16 days	DPC	Cardiomyopathy, Afib		
#27	74	F	L calf necrotizing soft tissue infection	Necrosis of skin, subcu-taneous tissue, & fascia	Infection	Class IV, Severe Sepsis	>500 cm^2	T-0	2 days	pus/exudate	Y	N	N	Y	Y	23 days	STSG + NPWT	Afib, DM, Morbid obesity: BMI = 43, CRI, Lymphedema	Partial take of initial STSG requiring repeat STSG	

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#28	34	M	L calf necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Trauma	Class IV, Sepsis	400 cm^3	T-0	5 days		Y	N	Y	Y	Y	5 days	DPC	Smoker		
#29	41	M	L calf necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV	240 cm^3	T-0	1 day	pus	Y	N	N	N	Y	8 days	DPC	Smoker		
#30	58	M	Lumbar necrotizing soft tissue infection & epidural abscess w/ osteomyelitis	Necrosis of skin, subcutaneous tissue, fascia & muscle w/ deep seated abscess & pyomyositis	Infection	Class IV, Sepsis	236 cm^3	T-0	2 days	pus	Y	N	Y	Y	Y	7 days	DPC	HTN, DM, BMI = 17, Malnutrition, Smoker, CRI		
#31	42	M	R thigh necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, fascia, & muscle w/ pyomyositis	Infection	Class IV, Septic Shock	600 cm^3	T-0	2 days	pyomyositis	Y	N	Y	Y	Y	16 days	DPC	CAD, HTN, DM, Obesity: BMI = 38, ESRD		
#32	43	F	L thigh necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Severe Sepsis	750 cm^3	T-0	3 days	pus	Y	Y	Y	Y	Y	6 days	DPC	HTN, DM, Obesity: BMI = 37		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#33	45	M	RUE (axilla to wrist) necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Septic Shock	1600 cm^2	T-0	3 days		Y	Y	Y	Y	Y	see outcome	DPC	DM, ARF, Rhabdomyolysis	Partial take of initial STSG requiring subsequent staged STSG & secondary intention closure over several mos.	
#34	44	F	RUE abscess & soft tissue infection	Deep seated abscess & cellulitis	Infection	Class IV, Sepsis	27 cm^3	T-0	3 days	pus	Y	Y	N	Y	Y	11 days	DPC	Morbid Obesity: BMI = 42, IVDA		
#35	77	F	Bil. Thighs necrotizing soft tissue infection	Necrosis of skin & subcutaneous tissue	Trauma	Class IV, Septic Shock	L: 1377 cm^3 R: 252 cm^3	T-1	2 days		Y	N	Y	Y	Y	R: 12 days L: N/A 2° death	DPC	Afib on coumadin, Obesity: BMI = 31, CRI, Coagulopathy		Death HD57[2]
#36	19	F	Abd wall necrotizing soft tissue SSI	Necrosis of skin & subcutaneous tissue	Infection	Class IV, Sepsis	630 cm^3	T-0	4 days	pus	Y	N	N	Y	Y	4 days	DPC	Recurrent hidradenitis suppurativa w/ abscesses, DM, Morbid obesity: BMI =~ 58		
#37	27	M	L calf soft tissue infection	Deep space soft tissue infection w/ abscess & cellulitis	Infection	Class IV, Sepsis	80 cm^2	T-0	2 days	pus	N	N	Y	Y	NT	5 days	DPC	Obesity: BMI = 30		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#38	20	F	Pilonidal soft tissue infection	Deep space soft tissue infection	Infection	Class IV, Sepsis	84 cm^3	T-0	4 days		CBC N/A	N	Y	Y	NT	7 days	DPC	Morbid obesity: BMI = 43		
#39	57	M	Fournier's gangrene & L buttock necrotizing soft tissue infection & ischiorectal abscess	Necrosis of skin, subcutaneous tissue, & fascia w/ deep seated abscess	Infection	Class IV, Septic Shock	1000 cm^3	T-2	3 days	pus	Y	N	Y	N	NT	34 days	DPC	HTN, DM, Morbid obesity: BMI = 47, Smoker, ARF		
#40	47	M	L forearm, L thigh/ buttock necrotizing soft tissue infection & rhabdomyolysis	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Trauma	Class IV, Severe Sepsis±	LUE: 150 cm^3 LLE: 90 cm^3	T-0	LUE = 4 days LLE = 2 days		Y	Y	N	Y	NT subsequent L thigh tissue Cx's positive±	LLE: 4 days LUE: N/A 2° death	DPC	Hep/ Alcohol cirrhosis, Obesity: BMI = 34, ARF/Rhabdomyolysis		Death HD15[3]
#41	65	F	Abd wall & L flank (R anter. axillary line to L posterior axillary line) necrotizing deep SSI 2° enteric fistula	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	3000 cm^3	T-0 Modified NPWT; subsequent NPWT	3 days		Y	Y	Y	Y	Y	77 days	DPC	Afib, HTN, DM Obesity: BMI = 38, ARF/CRI	Wound closure complicated by enteric fistula	

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#42	56	M	R calf/foot necrotizing soft tissue infection w/ abscess & osteomyelitis	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone; BKA indicated - pt declined	Infection	Class IV, Sepsis	180 cm^3	T-0	1 day	Pus	Y	Y	N	Y	Y	Lost to F/U	N/A	DM, Obesity: BMI = 32		
#43	43	F	L thigh & flank necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Septic Shock	thigh: 900 cm^3 flank: 608 cm^3	T-2	2 days	dishwater effluent	Y	N	Y	Y	NT	65 days	STSG + NPWT	Mixed Connective Tissue disease, Scleroderma, Lupus		
#44	73	M	L calf necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue; & cellulitis	Infection	Class IV, Severe Sepsis	345 cm^2	T-0	2 days (bedside)		N	N	Y	Y	Y	9 days	STSG + NPWT	CAD, Obesity: BMI = 39, DJD LLE phlebitis & chronic edema		
#45	73	F	Torso, flank, back, & bil. groin necrotizing soft tissue infection 2° Calciphylaxis	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	400 cm^2	T-0	2 days (bedside)	pus	Y	N	Y	Y	Y	Expired HD#27*	N/A	Calciphylaxis, CAD, HTN, DM, Obesity: BMI = 30, ESRD		Death HD27[4]

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#46	78	F	L calf soft tissue infection	Necrosis of skin & subcutaneous tissue	Trauma	Class IV, SIRS	350 cm^2	T-0	3 days		Y	N	N	Y	NT	6 days	DPC	CAD, Steroid-dependent COPD		
#47	64	M	L gluteal pyomyositis	Pyomyositis	Infection	Class IV, Sepsis	600 cm^2	T-0	1 day	pus	Y	N	N	Y	Y	5 days	DPC	N/A		
#48	47	M	L foot/ankle necrotizing soft tissue infection & osteomyelitis requiring BKA	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone	Infection	Class IV, Severe Sepsis	200 cm^2	T-0	2 days	pus	Y	Y	Y	Y	Y	11 days	DPC	DM		
#49	31	F	L neck & chest necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia with abscess	Infection	Class IV, Sepsis	>25 cm^2	T-2	3 days	pus	Y	N	Y	Y	NT	10 days	DPC	Crohns		
#50	41	F	L thigh necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia w/abscess	Infection	Class IV, Sepsis	144 cm^3	T-0	3 days	pus	N	N	Y	Y	Y	3 days	DPC	DM, Obesity: BMI = 37		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#51	66	M	R calf necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	>120 cm^2	T-0	N/A*	pus	Y	N	Y	N	Y	Expired HD#2*	N/A	Cardiomyopathy; A fib, HTN, Morbid obesity: BMI = 69, PVD, Hep C		Death HD2[5]
#52	78	M	R flank necrotizing soft tissue infection 2° bowel perf.	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	>740 cm^2	T-0	5 days	fecal soilage & purulence	Y	N	Y	Y	Y	8 days	DPC	DM, Obesity: BMI = 33		Death HD22[6]
#53	89	F	Abd wall necrotizing soft tissue infection	Necrosis of skin & subcutaneous tissue	Infection	Class IV, Severe Sepsis	480 cm^2	T-0	1 day		Y	N	Y	Y	N	3 days	DPC	HTN, Anemia		
#54	58	F	Laparotomy site deep SSI S/P strangulated ventral hernia	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Severe Sepsis	3520 cm^3	T-0	2 days		Y	N	N	Y	N	see outcome	Secondary intention	HTN, Morbid obesity: BMI = 49	Recurrent wound infection S/P DPC requiring reexploration & secondary intention closure over several wks	

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#55	33	M	R calf necrotizing soft tissue infection & R foot osteomyelitis	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone; BKA indicated pt's family declined	Infection	Class IV, Septic Shock	1200 cm^2	T-0	3 days		Y	Y	N	Y	Y	55 days	DPC	DM polyneuropathy, Obesity: BMI = 31, ARF/CRF, HD, Residual anoxic encephalopathy, Rhabdomyolysis		
#56	39	F	Abd wall acute on chronic soft tissue infection @ site of prior colostomy takedown	Soft tissue infection w/ abscesses	Infection	Class IV, Sepsis	216 cm^2	T-0	5 days	pus	N	N	Y	Y	Y	5 days	DPC	DM, Morbid obesity: BMI = 48		
#57	59	F	R shoulder necrotizing soft tissue infection w/pyomyositis & cellulitis	Necrosis of skin, subcutaneous tissue, fascia, & muscle w/pyomyositis & cellulitis	Infection	Class IV, Severe Sepsis	400 cm^2	T-0	3 days	pus	Y	Y	Y	Y	Y	7 days	DPC	HIV, CHF, HTN, Hep. C, IVDA		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#58	53	M	L scrotum complex soft tissue infection w/ abscesses	Soft tissue infection w/abscesses	Infection	Class IV, Sepsis	120 cm^3	T-0	2 days	pus	Y	N	N	Y	Y	2 days	DPC	HTN, Obesity: BMI = 35		
#59	81	F	R calf degloving injury w/soft tissue necrosis	Pressure necrosis of skin & subcutaneous tissue 2° hematoma	Trauma	Class IV	475 cm^2	T-0	2 days		N	N	N	N	NT	2 days	STSG + NPWT	Afib on coumadin, HTN, RA on steroids		
#60	65	M	R lat. abd wall & R flank necrotizing soft tissue infection 2° bowel perf.	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Infection	Class IV, Septic Shock	1344 cm^2	T-0 Modified NPWT; subsequent NPWT	2 days	fecal soilage & pus	Y	Y	Y	Y	Y	see outcome	see outcome	R retroperitoneal colon perf. requiring ex-lap, end ileostomy, & cecostomy tube. Hx of retroperitoneal liposarcoma requiring resection & adjuvant Cyberknife radiation; HTN, Obesity: BMI = 33, VDRF, CRI	Recurrent sepsis & failed initial DPC. Wound re-explorations, debridements, & staged reconstructions then done over several mos.	

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#61	39	F	Bil. thigh degloving injuries w/necrotizing soft tissue infection	Necrosis of skin & subcutaneous tissue	Trauma	Class IV, Severe Sepsis*	L: 648 cm^2 R: 756 cm^2	T-0	4 days		Y	N	Y	Y	NT subsequent tissue Cx's positive*	59 days	Staged STSG	Cardiomyopathy, HTN, Obesity: BMI = 30, Malnutrition, ARF, Coagulopathy	Partial take initial STSG requiring subsequent serial staged STSG	
#62	47	M	Abd wall & bil. thigh necrotizing soft tissue infection & Fournier's gangrene.	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	≥2000 cm^2	T-0 Modified NPWT; subsequent NPWT	2 days		Y	N	Y	Y	Y	see outcome	Wound complexity & CVA required staged STSG & DPC over several mos.	HTN, DM, Obesity: BMI = 35, Malnutrition, CRI, CVA	Penile necrosis & urethral erosion/ necrosis 2° to necrotizing soft tissue infection & subsequent NPWT	
#63	59	M	R foot & calf necrotizing soft tissue injury requiring AKA	Necrosis of skin, subcutaneous tissues, fascia, & muscle	Infection	Class IV, Septic Shock	200 cm^2	T-0 Modified NPWT	2 days		Y	N	Y	Y	Y	45 days	DPC	Chronic hepatic failure on transplant list		
#64	26	M	L thigh deep seated abscess cavity/ infected hematoma S/P GSW	Deep-seated abscess cavity/infected hematoma	Trauma	Class IV, Septic Shock	72 cm^3	T-0	4 days	infected hematoma	N	N	Y	Y	Y	excluded 2° type of closure	Secondary Intention	HTN, Morbid obesity: BMI = 54, Smoker		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT: WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90	Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome: Wound related complications	Outcome: Mortality
#65A	65	M	R thigh Morel-Lavallee injury w/ infected hematoma	Deep seated infected hematoma	Trauma	Class IV, Septic Shock*	800 cm^2	T-0 Modified NPWT; subsequent NPWT	2 days Bedside		Y	Y	Y	Y	N despite high clinical concern for infection*	12 days	DPC	Obesity: BMI = 30	see Case 65B	
#65B			R thigh Morel-Lavallee injury w/ infected hematoma & necrosis	Necrosis of skin, subcutaneous tissue & fascia	Trauma	Class IV Septic Shock	250 cm^2	T-0	5 days	murky	Y	N	Y	Y	Y	8 days	DPC	see Case 65A	5 mos. S/P initial DPC, delayed-recurrent infection noted. Reopening of wound & subsequent DPC effected	
#66	74	M	L hip necrotizing soft tissue infection & osteomyelitis	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone	Infection	Class IV, Septic Shock	150 cm^2	T-1	3 days		Y	N	Y	Y	NT	N/A (D/C w/NPWT 12 days S/P T-0 f/u care @ other facility)*	N/A	MRSA bacteremia from AICD infection, CHF, Cardiomyopathy, Afib on coumadin HTN, Paraplegia		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#67	35	F	Abd wall (anter. Axillary line to anter. Axillary line) necrotizing soft tissue infection & deep SSI	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	3600 cm^3	T-0	4 days	pus	Y	Y	N	Y	NT	22 days	DPC	Morbid obesity: BMI = 41, Smoker	Failed initial DPC required reopening & subsequent DPC	
#68	45	F	R thigh/groin necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	450 cm^2	T-0	2 days	pus	Y	Y	Y	Y	Y	6 days	DPC	HTN, DM, Morbid obesity: BMI = 47, CRI		
#69	59	F	L calf & foot necrotizing soft tissue infection & osteomyelitis requiring BKA	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone	Infection	Class IV, Septic Shock	175 cm^2	T-0	3 days	frank pus	N	Y	N	Y	Y	7 days	STSG	HTN, alcoholic hepatitis		
#70	30	M	Abd wall, L groin, & L iliac area necrotizing soft tissue infection 2° bowel perf.	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Septic Shock	975 cm^3	T-0	3 days	pus	Y	Y	Y	Y	Y	20 days	DPC	HTN, Obesity: BMI = 31		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Puru-lence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complica-tions	Mortality
#71	40	M	L foot & calf soft tissue infection	Multiple deep seated abscess cavities & myositis	Infection	Class IV	>240 cm^2	T-0	2 days	pus	N	N	N	Y	N	2 days	DPC	Chronic hepatic insufficiency from Hep C, Thrombocy-topenia		
#72	63	M	Presacral, perineal, perianal, & perirectal necrotizing soft tissue infection w/ abscesses 2° acute on chronic pilonidal disease, hidradenitis, & Marjolin's type squamous cell CA	Necrosis of skin, subcu-taneous tissue, & fascia	Infection	Class IV, Severe Sepsis	1500 cm^3	T-0	3 days	pus	Y	Y	N	N	Y	see out-come	STSG	Acute on chronic hidradenitis & Marjolin's type Squamous cell CA of sacral, gluteal, & perianal area	Marjolin's type Squamous cell CA requiring surgery, CTX, & RT. STSG subsequently effected several mos. S/P resection.	
#73	54	F	L calf necrotizing soft tissue infection	Necrosis of skin & subcu-taneous tissue	Infection	Class IV	400 cm^2	T-0	3 days	pus	N	N	N	Y	Y	5 days	STSG	MI, Obesity: BMI = 34		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#74	67	F	L buttock necrotizing soft tissue infection w/ abscess	Necrosis of skin, subcutaneous tissue, & fascia w/ abscess	Infection	Class IV, Septic Shock	300 cm^2	T-3	3 days	pus	Y	N	Y	Y	NT	33 days	DPC	HTN, ARF/CRI		
#75	37	F	Perineal abscess, necrotizing soft tissue infection w/ perineal abscess & ischial osteomyelitis	Necrosis of skin, subcutaneous tissue, fascia, muscle, & bone	Infection	Class IV, Severe Sepsis	150 cm^3	T-0	6 days	pus	Y	Y	N	Y	Y	6 days	STSG	DM, BMI = 17, Malnutrition, ESRD, Failed kidney/ pancreas transplant, paraplegia		
#76	79	M	Abd wall/R subcostal abscess	Deep-seated abscess	Infection	Class IV	200 cm^3	T-0	6 days	pus	no labs	N	Y	N	Y	29 days	DPC	MI, HTN, DM, CRI		
#77	18	M	Pilonidal soft tissue infection	Infected cyst w/ pilonidal soft tissue infection	Infection	Class IV	264 cm^3	T-0	3 days	pus	no labs	N	N	Y	NT	15 days	DPC	Spina bifida occulta; Obesity: BMI = 34		
#78	70	M	R foot necrotizing soft tissue infection & deep seated abscess	Necrosis of skin, subcutaneous tissue, & fascia	Infection	Class IV, Severe Sepsis	>138 cm^2	T-2	3 days		Y	N	Y	Y	Y	12 days	STSG	HTN		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#79	27	F	Bil. calf crush injury w/ degloving & necrotizing soft tissue infection	R: necrosis of skin, subcutaneous tissue, fascia, & muscle; L: necrosis of skin & subcutaneous tissue w/ hematoma	Trauma	Class IV, Severe Sepsis	R: 920 cm^2 L: 200 cm^2	T-0	R = 2 days L = 4 days	turbid fluid	Y	N	Y	Y	Y	R: 19 days L: 8 days	STSG + NPWT	Lymes disease, Obesity: BMI = 36		
#80	82	M	R calf wounds x2 S/P saphenous vein harvest	Necrosis of skin & subcutaneous tissue, w/ abscess	Infection	Class IV, Sepsis	75 cm^2	T-0	2 days		N	N	Y	Y	Y	12 days	STSG + NPWT	Cardiomyopathy, CHF, HTN, Malnutrition		
#81	51	F	Abd wall soft tissue infection & deep SSI S/P recurrent ventral hernia repair w/ bioprosthetic	Deep seated abscess	Infection	Class IV, Severe Sepsis	400 cm^2	T-0	3 days	pus	Y	N	Y	Y	Y	17 days	DPC	Multiple recurrent ventral hernia repairs, HTN, Obesity: BMI = 35		

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Purulence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complications	Mortality
#82	75	M	RLE crush injury w/ traumatic AKA	Necrosis of skin, subcutaneous tissue, fascia, & muscle	Trauma	Class IV, Septic Shock	>1600 cm^2	T-0	2 days		Y	N	N	Y	NT	36 days	STSG	HTN, Obesity: BMI = 39, CVA		
#83	35	F	Abd wall SSI	Necrosis of skin, subcutaneous tissue, fascia, & muscle w/ abscesses	Infection	Class IV, Sepsis	600 cm^3	T-0	5 days	pus	Y	Y	Y	Y	Y	18 days	DPC	Obesity: BMI = 33		
#84	60	M	Abd wall necrotizing soft tissue infection	Necrosis of skin, subcutaneous tissue & fascia w/deep-seated, abscess & infected hematoma	Infection	Class IV, Septic Shock	400 cm^3	T-0	4 days	murky fluid	Y	Y	Y	Y	Y	see outcome	STSG + NPWT	CAD, Obesity: BMI = 30, ESRD on HD	Pt declined STSG	

Table 1 *Continued*

Case	Age	Sex	Wound	Degree of tissue destruction with or without infection	Etiology	Wound class & degree of sepsis	Wound size*	Timing of NPWT†	Dressing Chg S/P initial NPWT	Puru-lence	Sepsis/SIRS, <48 hours prior to NPWT				Wound Cx Pos. <48 hours prior or <24 hours after NPWT	Time from T-0 to wound closure	Type of closure	Comorbidities	Outcome	
											WBC>12 or <4 or band>10%	Fever >38 or <36	RR >20	HR >90					Wound related complica-tions	Mortality
#85	35	F	Sacral/ ischial decubiti	Necrosis of skin, subcu-taneous tissue, & fascia	Decubiti	Class IV	sacral: 189 cm^3 L ischial: 120 cm^3; R ischial: 196 cm^3	T-0¶	5 days		N	N	N	Y	NT	see out-come	STSG & Secondary Intention**	Spina bifida w/ para-plegia, Morbid obesity: BMI = 61, Malnutrition	Partial take of STSG leading to secondary intention closure over subsequent weeks.	
#86	46	M	Abd necrotizing soft tissue infection S/P per-forated appendi-citis	Necrosis of skin, subcu-taneous tissue, & fascia	Infection	Class IV, Severe Sepsis	720 cm^3	T-0	3 days	dishwater appear-ance	Y	N	Y	Y	Y	7 days	DPC	HTN, DM, Morbid obesity: BMI = 54		

Modified NPWT, gauze based negative pressure system; NPWT, negative pressure wound therapy; POD8, postoperative day #8; SSI, surgical site infection; DPC, delayed primary closure; STSG, split-thickness skin graft; Subsequent NPWT, polyvinyl alcohol or polyurethane foam based NPWT.

Deaths during hospital stay(HD) or within 30 days of discharge: [1]HD36 due to septicemia & refractory myelodysplastic syndrome. [2]HD#57 due to COPD/CAD/CHF. [3]HD#15 due to Hepatorenal Failure/Rhabdomyolysis. [4]HD#27 due to refractory calciphylaxis. [5]HD#2 due to multisystem organ failure from septic shock. [6]HD#22 due to Pulmonary Embolism/Myocardial linfarcation.

*Due to the three dimensional characteristics of these wounds, including crevices, tunneling and flaps, exact wound dimensions either cm^2 or cm^3 could not be obtained in all cases.

†Timing of NPWT= **T-0:** NPWT placement at initial surgical intervention. **T-1:** NPWT placement at first subsequent surgical intervention. **T-2:** NPWT placement at second subsequent surgical intervention. **T-3:** NPWT placement at third subsequent surgical intervention.

‡Within 48 hours postoperative.

§Two of eight surgeries done by separate partnering physicians.

¶S/P multi failed tissue advancement flaps; length of stay>270 days before referral.

Wound aetiology

Trauma was the aetiology in 25/97 (26%) of wounds; infection in 69/97 (71%) of wounds; and decubiti in 3/97 (3%) of wounds. Of those related to a primary infectious cause, 6/69 were post surgical, 7/69 were Fournier's gangrene, and 8/69 pyomyositis. An uncontrolled enteric fistula (present prior to the use of NPWT) was the aetiology in 1/97 cases. Bowel perforations led to 4/97 wounds.

Wound classification

All wounds, 97/97 (100%), met CDC Class IV criteria due to the presence of contamination: infection and/or tissue necrosis (25). Classification of the type of contamination was infection in 86/97 (89%) of wounds, (with or without associated necrosis); and tissue necrosis in 11/97 (11%), (*without* evidence of infection). All wounds with infection were treated with systemic antibiotics. All wounds with tissue necrosis required sharp/excisional debridement in the operating room.

Presence of systemic inflammatory response syndrome (SIRS)/degree of sepsis

Based on established international criteria: 4/86 (5%) of patients met SIRS criteria; 24/86 (28%) met sepsis criteria; 19/86 (22%) met severe sepsis criteria; and 31/86 (36%) met septic shock criteria (26–28). The cause of SIRS/sepsis was because of the acute wound aetiology (trauma or infection) in all cases (Figure 1).

Wound size

The average surface area was 619 cm^2 where length and width was measured. The average wound volume was 786 cm^3 when length, width and depth measurements were taken. Note, because of the three-dimensional characteristics of these wounds, including crevices, tunnelling and flaps, exact wound dimensions either cm^2 or cm^3 could not be obtained in all cases (Table 2).

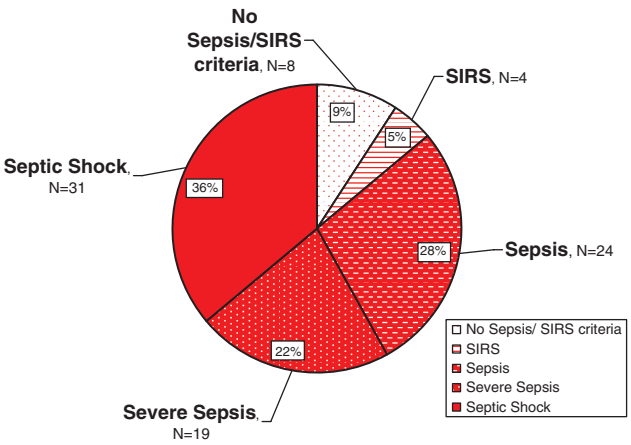

Figure 1 Patient characteristics re: systemic inflammatory response syndrome, sepsis, severe sepsis and septic shock.

Timing of NPWT

The timing of initial placement of the NPWT was at the first surgical intervention (T-0) in 81/97 wounds; at the second surgical intervention (T-1) in 9/97 wounds; at the third surgical intervention (T-2) in 6/97 wounds; and at the fourth surgical intervention (T-3) in 1/97 wounds.

Timing for placement of the NPWT, if done other than (T-0), was because of partnering physicians providing the initial surgical intervention and not electing to institute NPWT at that time. With wound contamination, and/or infection present in re-evaluation, these cases met inclusion criteria for this study. Timing of NPWT was then noted.

The V.A.C.® polyurethane system was used in 96/97 wounds, and the polyvinyl sponge in 1/97 wounds. Polyvinyl sponges were used when there was exposed bowel. Gauze-type NPWT was used in 7/97 wounds (elected by partnering physicians at the time of their surgical intervention). In 6/7 of these cases, foam-based NPWT was used at the subsequent surgical intervention. The remaining patient had subsequent delayed primary closure.

Dressing change status post initial placement

Timing of NPWT dressing changes was determined based on current clinical standards combined with individual patient and wound assessments (6,17,28). Because of the presence of tissue necrosis and/or infection in the initial stages of these cases, the NPWT system was changed more frequently during the early phase of wound care. The average time to NPWT change post initial placement was 2·9 days.

Purulence

Purulence was present in 62/97 (64%) of wounds. This was noted as a separate wound parameter irrespective of any cultures that were taken. Purulence was defined by typical appearance, and recorded as present if there was at least enough volume to be collected by syringe.

Wound culture

Wounds were cultured if there was concern for infection based on clinical evaluation; hence, not all wounds were cultured (e.g. traumatic wounds at initial intervention). In order to corroborate the acuity of these wounds, to clarify their features at initial evaluation, and to standardise wound assessments, cultures were recorded at the initial time of surgery and placement of NPWT (time interval defined as cultures $\leq$48 hours prior to or $\leq$24 hours after the initial surgery and use of NPWT). Cultures were positive in 62/69 (90%) of wounds (Figure 2).

Type and timing of wound closure

Wounds were closed with delayed primary suturing, split thickness skin grafts and/or secondary intention healing. The average time to closure was 17·1 days, median 10 days, and mode 6 days.

Table 2 Patient/wound characteristics*

Patients ($n = 86$)	Number(%)	Wounds ($n = 97$)	Number (%)
Demographics		Aetiology	
Male	50 (58)	Infection	69 (71)
Female	36 (42)	Trauma	25 (26)
Age, mean (SD), years	52 (17)	Decubiti	3 (3)
Risk factors		Classification of contamination	
Cardiovascular	48 (56)	Infection (with or without necrosis)	86 (89)
Diabetes	34 (40)	Necrosis (without infection)	11 (11)
Obesity	53 (62)		
Tobacco	13 (15)	Location	
		Upper extremity	8 (8)
Degree of sepsis		Torso	41 (42)
Sepsis	24 (28)	Lower extremity	48 (50)
Severe sepsis	19 (22)	Combined areas	2 (2)
Septic shock	31 (36)		
SIRS	4 (5)	Size	
Ø sepsis/SIRS criteria	8 (9)	Mean	617 cm^2(53 wounds)
			786 cm^3(43 wounds)
			45 cm linear (1 wound)
		Upper extremity	
		Mean (SD ± 1)	637 cm^2(608–666)
			1095 cm^3(279–1911)
		Torso	
		Mean (SD ± 1)	754 cm^2(502–1005)
			830 cm^3(636–1024)
		Lower extremity	
		Mean (SD ± 1)	550 cm^2(351–748)
			583 cm^3(497–690)

SD, standard deviation; SIRS, systemic inflammatory response syndrome.
*Note that, because of the three-dimensional characteristics of these wounds, including crevices, tunnelling and flaps, exact wound dimensions of either cm^2 or cm^3 could not be obtained in all cases.

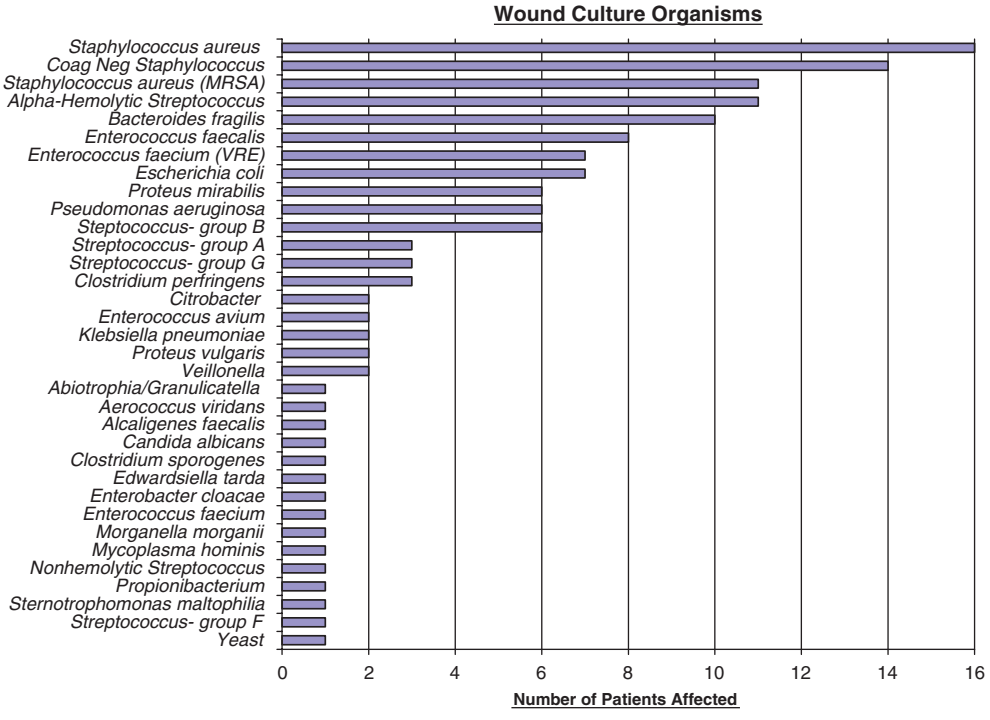

Figure 2 Wound culture organisms and number of patients affected (*Corynebacterium* also found in 14 wounds; but not felt to be a causative organism).

Wounds excluded from the time-to-closure calculation were as follows: 4/97 because of patient death prior to wound closure; 2/97 because of comorbidities delaying wound closure (e.g. presence of malignancy and cerebrovascular accident); and 7/97 secondary intention 'closures', (i.e. due to lack of accepted published criteria for defining wound 'closure' in secondary intention healing) (3,15). Additional exclusions included 2/97 wounds lost in follow up and 1/97 wound wherein the patient refused split-thickness skin graft.

Comorbidities

Patient comorbidities were recorded based on a physiologic systems approach. Comorbidities were defined as a system abnormality that predated the current hospital admission. Obesity, if present, was noted as well and body mass index recorded.

Note, specific acute organ system abnormalities were not recorded in the Supporting information (unless contributing to a patient's death), as their presence was represented in the diagnosis of severe sepsis and/or septic shock.

Outcome

Wound related complications

Wound complications were defined as either a delayed primary suture closure that required wound reopening, or a partial take of a split-thickness skin graft. Wound complications were present in 6/81 (8%) of cases. (Reference the above for the excluded wounds).

Deaths

Patient deaths were noted in 6/86 (7%) and as follows: 2/6 as a result of continued patient deteriorations from established comorbidities (e.g. fulminant calciphylaxis and refractory myelodysplastic syndrome); 2/6 related to irrecoverable septic shock (shock state present at the time of admission and prior to wound intervention); 1/6 deaths occurred on hospital day 22 as a result of a pulmonary embolus and myocardial infarction; 1/6 deaths occurred on hospital day 57 as a result of cardiopulmonary complications from chronic obstructive pulmonary disease and coronary artery disease. No deaths appeared directly related to NPWT.

Discussion

Negative pressure wound therapy is in widespread use and its role in wound care worldwide is rapidly expanding (7,16,17,19–23,28–31). FDA indications for NPWT are 'chronic, acute, traumatic, subacute and dehisced wounds, partial-thickness burns, ulcers (such as diabetic or pressure), flaps and grafts' (32). However, several areas of concern arise in the contemporary use of NPWT in acute wounds. First, acute wounds often have tissue necrosis. Empiric practice of NPWT includes such cases, though published contraindications include wounds with necrosis/eschar (29,30,33). Second, acute wounds are often of infectious aetiology; yet, current published literature does not confirm decreasing bacterial loads in wounds managed with NPWT (9,34–36). Third, case reports exist for infection/sepsis occurring with the use of NPWT in acute wounds (7,21,37). Fourth, acute wounds caused from war, terrorism and natural disasters are often caused by significant force, resulting in large wounds; however, there is limited published literature of NPWT in such cases (19–23). Lastly, NPWT in the Third World is expanding, proposed as being of 'great value in treating severe wounds in underdeveloped countries' (7). However, lack of resources for comprehensive acute wound care, lack of sterile supplies, loss to follow-up and lack of published data in this setting are noteworthy.

Our study aimed to assess many of the above concerns. The wounds depicted in this series were all contaminated, and the vast majority infected. Many of the traumatic extremity wounds were created by such force that either amputation had occurred, or was required subsequently. Wounds of infectious aetiology were typically complex, polymicrobial, necrotising soft tissue processes. Average wound dimensions were large. Thus, the wound cohort in this study mirrors current empiric, global acute wound NPWT practice.

Limitations to our study include the lack of a control group; yet, publications to date reflect the inherent difficulty of prospective, randomised trials in wound care (3,6–14). Though other observational study designs might have been used to compare wound care practices, our aim was not to document wound care superiority with NPWT. Rather, it was to review and assess the safety and efficacy of current empiric, expanding NPWT-related acute wound care practice, including our own. Separately, from a patient focused care perspective, there were practical needs to apply NPWT as opposed to non NPWT care in this patient cohort. For example, use of gauze-based wet-to-dry dressing changes would be comparatively painful; and frequent gauze dressing changes would have required higher levels of care because of increased needs of sedatives/analgesics and monitoring (38,39). In this regard, the large wound sizes and deep wound spaces of this patient cohort, mean wound sizes 617 cm^2 and 786 cm^3, were of particular concern. (Of note, a recent publication addressing pain level in gauze-based wound care compared to NPWT did not find less pain with NPWT. Yet that patient cohort was significantly different in having much smaller wound sizes: median size 4 cm in that cohort compared to 400 cm in this cohort). Another potential limitation relates to the heterogeneity of wound locations (albeit limited to the torso and extremities) and aetiology (traumatic and infectious). Yet with our stated aim it was important to include the heterogeneity described as it mirrors current empiric global NPWT-related acute wound care practice. Lastly, difficulty in quantifying fluid losses from large, open (wet-to-dry gauze-packed) wounds predisposes patients to renal insufficiency/failure, whereas NPWT accurately accounts for fluid losses. (Published acute wound care literature does not address pre-renal azotaemia. Yet, published cases have denoted much smaller wound sizes than our cohort, and so fluid shifts and pre-renal azotaemia expectedly of much less concern) (8–10,12,13,40). From this perspective, our study may in fact reflect a previously undescribed benefit of NPWT in large wounds.

Published data to date do not show clear outcome benefits for NPWT compared to contemporary non NPWT related wound care (3,6). However, published and accepted non outcome related benefits of NPWT validate its use (2,6,17). Contemporary NPWT related acute wound care is expanding *empirically,* in quantity and scope across the globe. Yet, several areas of concern are known regarding this contemporary expanded use of NPWT in acute wounds. Thus, it is important to assess the safety and efficacy of such expanded empiric, global NPWT practice. Based on our findings with NPWT in the largest known patient cohort of this type, NPWT appears safe and effective in managing acute, contaminated wounds including patients meeting sepsis criteria.

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