Use of Direct Peritoneal Resuscitation for Intra-Abdominal Catastrophes: A Technical Note

Matthew McGuirk, MD[1]
Research Fellow

Agon Kajmolli, MD[1]
Research Fellow

Mahir Gachabayov, MD[1]
Research Scholar

Ansab Haider, MD[1]
General Surgery Resident

Matthew Bronstein, MD[1]
Attending Surgeon

Dawn Spatz, MSN, FNP-BC[1]
Nurse Practitioner

Carlo Gwardshaladse, MPH, PA-C[1]
Physician Assistant

Rifat Latifi, MD, FACS, FICS
[2]The Felicien Steichen Professor and Chairman of Surgery
[1]Director, Department of Surgery

[1]Westchester Medical Center Valhalla, NY
[2]New York Medical College, Westchester Medical Center, Stamford, CT

ABSTRACT

Direct peritoneal resuscitation (DPR) involves instilling 2.5% dextrose peritoneal dialysate into the abdomen in an attempt to both resuscitate the patient and decrease systemic inflammation; 800cc are instilled in the first hour and 400cc/h are instilled each subsequent hour. DPR has been shown to decrease systemic inflammation, increase the rate of primary abdominal closure, lower the rate of intra-abdominal infections, and lower the rate of complications. It also increases blood flow to the intestines, helping to prevent ischemia and re-perfusion injury. We present the technique used for DPR in a patient with an intra-abdominal catastrophe, as well as the use of Kerecis® Omega3 Wound graft (Kerecis, Arlington, VA) and wound vacuum-assisted closure (VAC) for creation of a floating stoma.

INTRODUCTION

The management of patients suffering from intra-abdominal catastrophes is one of the most challenging problems a surgeon can face. Whether the patient presents post traumatic injury or intra-abdominal sepsis, operative and resuscitative management poses many challenges. While intravenous fluid and blood products help increase the intravascular volume, improve blood pressure, and decrease heart rate, ischemia of the visceral organs can persist, leading to the release of inflammatory cytokines. Direct peritoneal resuscitation (DPR) has been used to resuscitate a patient post-operatively, post damage-control surgery and/or post abdominal catastrophe . DPR is performed by infusing 2.5% dialysate into the abdomen, while simultaneously performing normal intravenous resuscitation. It has been shown to cause arte-

riole dilation, reducing end-organ ischemia. This effect is especially pronounced in the intestinal arterioles, which can be most affected by shock.[1]

Direct peritoneal resuscitation has been shown to significantly decrease the amount of time until definitive abdominal closure following damage-control laparotomy. It has also been shown to have a higher rate of primary fascial closure, and lower rates of intra-abdominal infections, complications, and ventral hernias.[2] A decreased amount of visceral edema and normalized body water ratios facilitate earlier abdominal closure.[3] Smith et al. showed a 68% definitive closure rate at a mean of 5.9 days, compared to a 43% closure rate at a mean of 7.7 days in patients without DPR. They also showed fewer days on a ventilator and a shorter ICU stay.[4] In

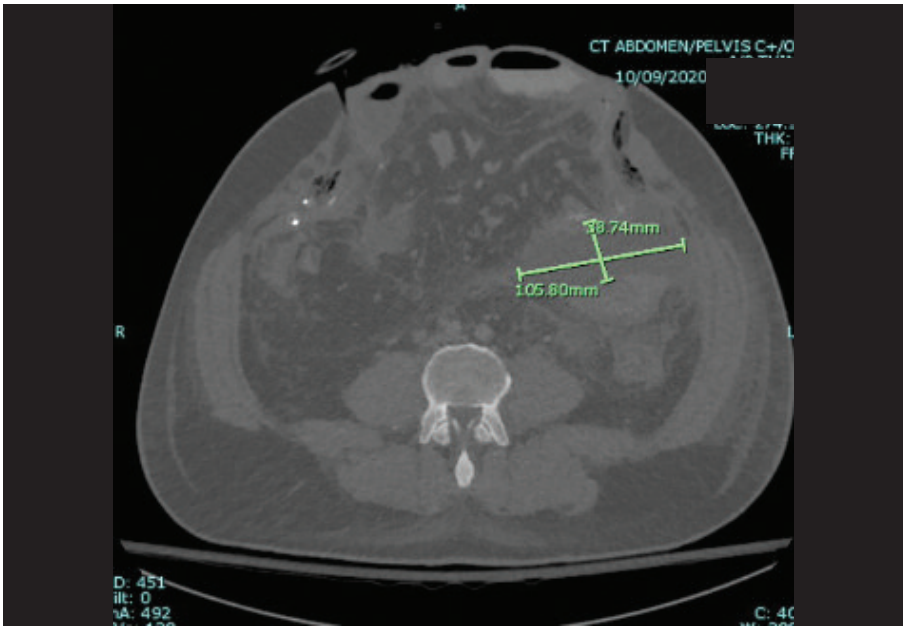

Figure 1. Pre-operative CT of the abdomen and pelvis.

Figure 2. Intra-abdominal content as one "Inflammatory mass".

Table I
Trends in lab values over the first 16 hospital days showing the effect of DPR

Hospital day	Days on DPR	WBC	Hgb	Hct	Neutrophil	Lymphocyte	NLR	LDH	CRP	Ferritin	D-dimer
1	0	41.2	9.2	28.9	90.4	1.6	56.5	243			
2	0	38.1	10.0	31.3	88.2	2.9	30.4				
3	0	19.0	9.6	30.2	82.9	5.8	14.3				
4	0	17.8	8.6	27.8	79.4	6.3	12.6				
5	0	15.8	8.1	26.6	79.0	5.0	15.8	286	21.0	519.0	14501
6	1	22.3	9.0	29.4	76.0	6.3	12.1	432	19.0	497.6	17604
7	2	12.8	7.1	23.4	73.3	10.6	6.9	212	21.0	486.7	8265
8	3	13.0	8.3	26.1				203	16.0	366.5	14576
9	4	16.2	7.8	25.4	82.1	8.4	9.8	301	15.0	428.4	
10	5	15.7	10.5	32.9	84.6	4.3	19.7		11.0	427.9	
11	6	15.2	9.4	29.4	83.5	7.4	11.3		6.4	388.7	
12	7	14.5	8.7	27.7	79.1	11.4	6.9		5.2		
13	8	14.7	8.6	27.5	80.3	9.5	8.5		9.2	317.3	
14	9	14.0	9.3	30.4	78.8	10.5	7.5		7.2	356.0	
15	10	12.3	9.4	30.1	77.6	10.7	7.6		6.7	327.4	
16	11	12.1	10.2	33.0						393.8	

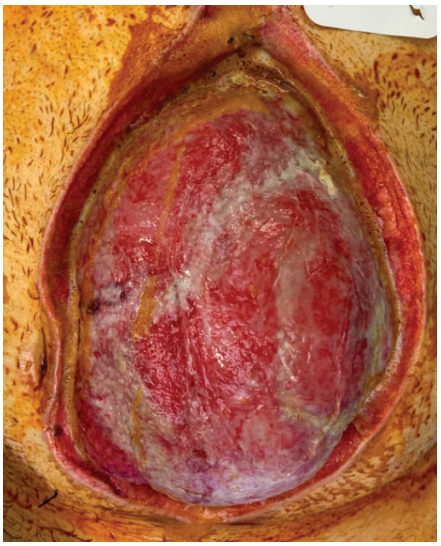

Figure 3. Significant decrease of "inflammatory mass" of open abdomen after 72 hours of DPR

Figure 4. Creation of a "floating ostomy" inside the abdominal wound VAC during our second case.

Figure 5. Ostomy appliance in place.

another study, Smith et al. reported similar findings; primary fascial closure was seen in 83% of patients who underwent DPR and 66% of patients who did not receive DPR. Patients who underwent DPR also had a lower rate of intra-abdominal abscess formation (3%) than patients who did not undergo DPR (14%).[5]

DPR has been shown to cause a significant increase in blood flow to the jejunum, ileum, spleen, and pancreas.[6] As a result, DPR has benefits for patients with intestinal ischemia and reperfusion injury. Crafts et al. showed that the 7-day survival rate in patients who underwent DPR treatment (60%) following ischemia-reperfusion injury was much greater than that in patients who did not have DPR treatment (30%).[7] The mechanism by which DPR increases intestinal blood flow appears to involve nitric oxide signaling pathways in the endothelium, as well as adenosine A1 receptor activation and the activation of glibenclamide-sensitive K+ channels.[8,9] Compared with conventional intravenous resuscitation, DPR causes significant vasodilation, and can even reverse vasoconstriction of the gut arterioles following IV resuscitation only.[10-12] We describe a case of a patient who underwent multiple exploratory laparotomies for intraabdominal catastrophe, requiring open abdomen management, managed with DPR. In addition, we used Kerecis® Omega3 Wound graft (Kerecis, Arlington, VA) to improve the process of skin grafting in the open abdomen.

SURGICAL TECHNIQUE

Our patient was a 42-year-old male with a past medical history of Crohn's disease, chronic back pain, opiate use, and anxiety who presented to an outside hospital with a small bowel obstruction. An exploratory laparotomy was performed with ileocecal mass resection. Due to edema of the bowel, an anastomosis could not be completed, and temporary closure was performed. Three days later an ileocecal anastomosis was performed. The abdomen was again left open and he returned to the operating room three days later for an abdominal washout. Two days later, he developed severe leukocytosis and increasing vasopressor requirements, with a white blood cell count of 50 k/mm^3. He was again taken to the operating room, where anastomotic breakdown was discovered. Due to a frozen abdomen, the surgeon could not mobilize the bowels enough to attempt a diverting ostomy, so a Malecot drain was placed in the anastomotic site and a Jackson-Pratt (JP) drain was placed in the right lower quadrant. He was then transferred to our institution for further management.

He was brought to our Surgical Intensive Care Unit (SICU) intubated and on 20mcg of norepinephrine. His white blood cell count on presentation was 41.2 k/mm^3 with a left shift of 90.4% neutrophils. His neutrophil-to-lymphocyte ratio was 56.5, which placed him at an extremely elevated risk of mortality. He was resuscitated and taken for a CT of his abdomen and pelvis to delineate his anatomy for surgical planning. CT showed multiple intra-abdominal collections and abnormal-appearing small bowel (Fig. 1). After some optimization, he was taken to the operating room for an abdominal exploration. He was found to have a frozen abdomen (Fig. 2), with the bowels severely inflamed, dilated, and adhered together. The decision was made to perform a resection of the anastomosis and leave him in discontinuity, and DPR was initiated. Two large drains (19 French) were placed in the upper abdomen and a wound vacuum-assisted closure (VAC) was placed on the abdomen. Wound VAC white foam was placed to protect the bowel and overlaid with black foam for VAC therapy.

DPR was started using 800cc of dialysate in the first hour and 400cc/h of dialysate each subsequent hour per the Kentucky protocol.[4,5] DIANEAL 2.5% dextrose peritoneal dialysis solution was used as the dialysate. Table I shows the trend in his lab values over the course of his DPR therapy; his WBC count, Neutrophil-to-Lymphocyte Ratio (NLR), LDH, CRP, Ferritin, and D-dimer all trended down.

He was taken back to the operating room on post-op day 3 for a re-exploration, abdominal washout, and floating ileostomy creation (Fig. 3). DPR was continued (Figs. 4 and 5). Indocyanine green was used to ensure viability of the stoma prior to leaving the operating room (Fig. 6). Upon return to the operating room four days later, the bowel edema and inflammation were once

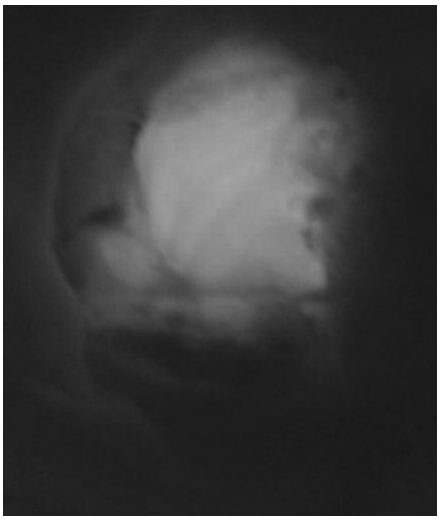

Figure 6. Indocyanine green demonstrating ostomy viability.

Figure 7. Post-operative view of open abdomen on DPR and functioning ileostomy.

Figure 8. Kerecis® Omega3 Wound graft (Kerecis, Arlington, VA) placement to aid with granulation tissue formation over the reduced inflammatory mass.

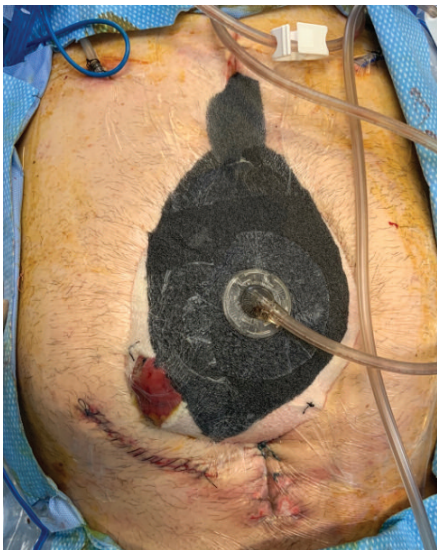

Figure 9. Wound VAC placement with the "floating ostomy" over Kerecis® (Kerecis, Arlington, VA) placement.

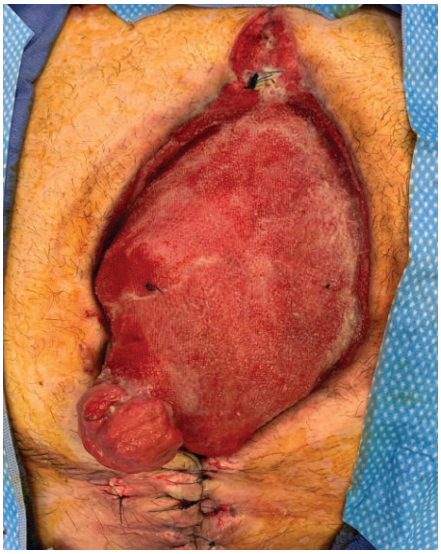

Figure 10. Healthy granulation tissue over the "inflammatory mass" and "matured" stoma post treatment with DPR and Kerecis® Omega3 Wound graft immediately before skin grafting.

again reduced and the ostomy was viable (Fig. 7). Four pieces of Kerecis® Omega3 Wound graft were placed to aid with the formation of granulation tissue over the wound and the wound VAC was placed overtop (Figs. 8 and 9). On hospital day 12 at our institution, he was successfully extubated and tolerated tube feeding via a post-pyloric Cortrak® feeding tube (Avanos Medical, Inc., Alpharetta, GA). DPR was continued for 11 days. He went back to the operating room for two additional VAC changes and one more placement of Kerecis® Omega3 Wound graft. The use of this graft allowed for the rapid formation of granulation tissue to enable placement of a skin graft to close the abdomen (Fig. 10).

DISCUSSION

The main benefit of incorporating DPR in our patient was the decrease in the systemic inflammatory response, bowel edema, and decrease of the abdominal "inflammatory" mass. His LDH, CPR, and ferritin continued to decrease from POD1 to POD3, while his D-dimer level decreased prior to an increase on POD3 when he went back to the operating room. LDH, CRP, ferritin, and D-dimer have all been shown to increase in times of inflammatory response by the body.[13-16] In a comparison of DPR to intravenous resuscitation, Matheson et al. showed that DPR decreased the levels of cytokines and inflammatory markers. It also downregulated the systemic damage-associated molecular patterns (DAMP) response.[17] There is also a downregulation of hepatic microRNA molecules associated with inflammatory cascades.[18] Another mechanism by which DPR downregulates the systemic inflammatory response is via the modulation of inflammatory interleukins. DPR causes a significant increase in the release of IL-10 in the liver and intestines and the downregulation of IL-6 and TNF-α, release, decreasing the inflammatory response.[19,20]

Another prognostic sign during sepsis is the neutrophil-to-lymphocyte ratio. Our patient's neutrophil-to-lymphocyte ratio of 56.5 upon presentation to our institution placed him at a very high risk of mortality. The neutrophil-to-lymphocyte (NLR) ratio can be used as a biomarker to predict a poor prognosis in patients with sepsis.[21-24] In fact, in 2017, Forget et al. reported that the normal range in healthy adult patients was 0.78-3.53.[25] On the morning that he went for his first surgery at our institution, our patient's NLR was 19.8. It continued to drop and reached 6.9 prior to the next operation 3 days later. In a prospective observational study of 333 patients, Liu et al. showed that an NLR of 11.11 (6.98-18.24) was associated with sepsis, a ratio of 22.67 (12.35-31.89) was associated with severe sepsis, and a ratio of 31.5 (22.56-46.94) was associated with septic shock.[26]

The decrease in systemic inflammation and bowel edema aided by DPR

allowed for the creation of a diverting ostomy to gain control over his infectious source and provided time to heal. In addition, the use of Kerecis® Omega3 Wound graft (Kerecis) allowed for the rapid formation of enough granulation tissue for skin grafting. Kerecis® is a relatively new product that has been proven to be beneficial for healing difficult wounds. It has been demonstrated to help decrease wound depth and surface area, and to help with diabetic foot wounds, as well as burn or traumatic wounds.[27-29] Magnusson et al. found that it provided a bacterial barrier for 24-48 hours.[30]

CONCLUSION

Direct peritoneal resuscitation can play an important role in decreasing systemic inflammation and allows for infectious source control and intra-abdominal healing in cases of intra-abdominal catastrophe. In addition, the use of Kerecis® Omega3 Wound graft can help shorten the time until skin graft. STI

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Tel. +1 415 704 3160
Email: info@surgicaltechnology.com
Internet: www.surgicaltechnology.com
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