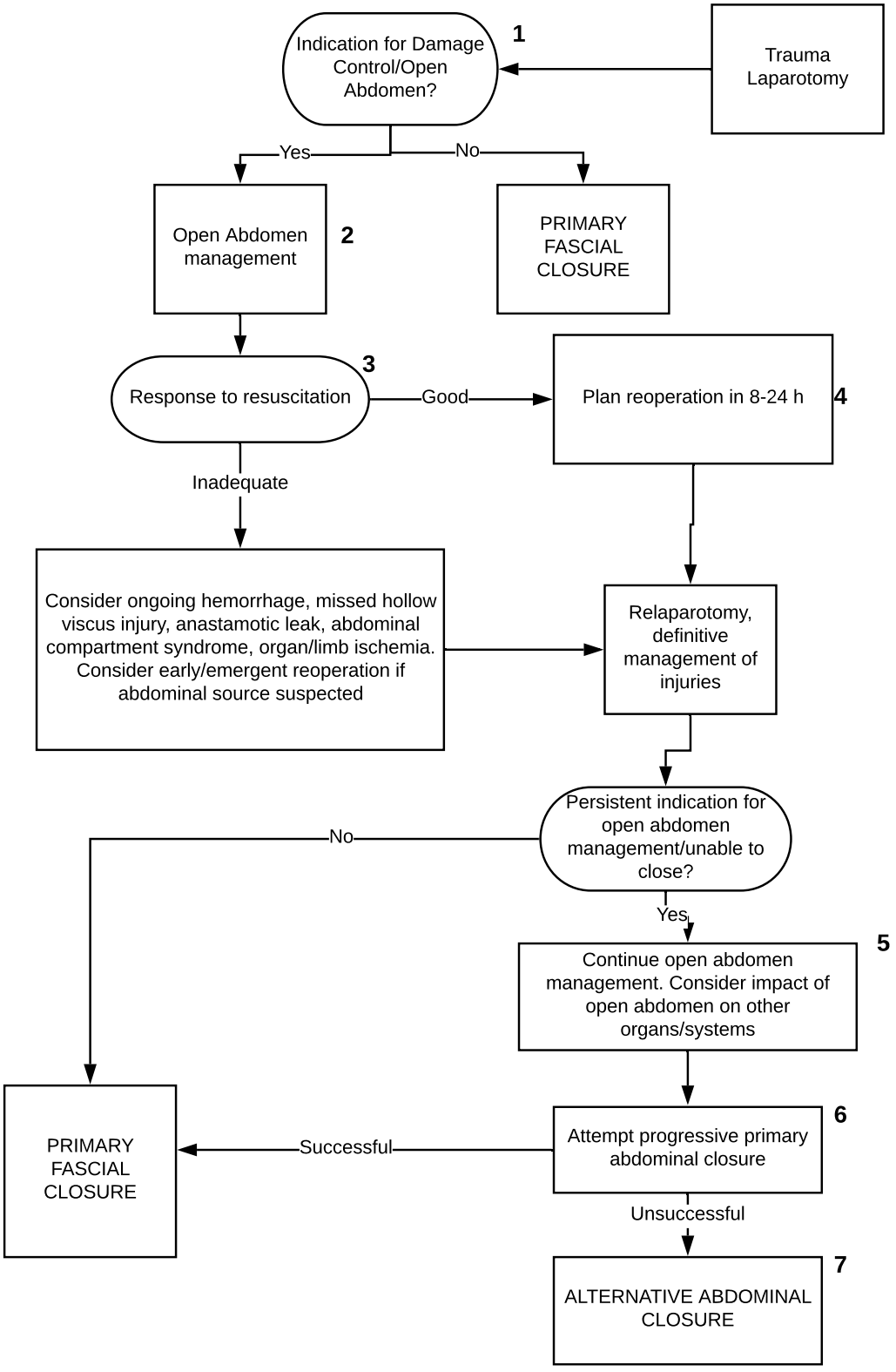
Indication for Damage Control/Open Abdomen?
1
Trauma Laparotomy
Yes
No
Open Abdomen management
2
PRIMARY FASCIAL CLOSURE
Response to resuscitation
3
Good
Plan reoperation in 8-24 h
4
Inadequate
Consider ongoing hemorrhage, missed hollow viscus injury, anastamotic leak, abdominal compartment syndrome, organ/limb ischemia. Consider early/emergent reoperation if abdominal source suspected
Relaparotomy, definitive management of injuries
Persistent indication for open abdomen management/unable to close?
No
Yes
Continue open abdomen management. Consider impact of open abdomen on other organs/systems
5
PRIMARY FASCIAL CLOSURE
Successful
Attempt progressive primary abdominal closure
6
Unsuccessful
ALTERNATIVE ABDOMINAL CLOSURE
7

1. Damage Control/Open Abdomen may be indicated during laparotomy for trauma if any of the following circumstances are noted:

a. Physiologic indicators suggest that operation should be abbreviated. Persistent hypotension, acidosis, core temperature <34°, and coagulopathy may signal impending death, and should prompt a damage control approach[13–17]. Historically, pH has been used to describe acidemia thresholds for damage control (pH<7.2), but more accurate measures of metabolic acid load such as lactate and base deficit are widely used and well validated[18,19]. Coagulopathy has traditionally been diagnosed via clinical observation of the surgical field, or by standard laboratory values (PTT/INR/Platelet Count/fibrinogen). However, recent work suggests that viscoelastic assays (thromboelastography [TEG] and thromboelastometry [ROTEM] may be important adjuncts in the assessment of clinical coagulopathy [20–22]. Other point-of-care tools (e.g. impedance aggregometry) may have an evolving role[23], but are not currently in common clinical use.

Surgical bleeding must be controlled prior to ending the operation, but endless futile searches for sources of diffuse coagulopathic hemorrhage are to be avoided. Peritoneal lavage for rewarming can be effective in reversing core hypothermia, but is disruptive to packing, and its effect on outcome is not known. Physiologic

trends - in addition to initial values – can help guide the decision for damage control, and with appropriate resuscitation and prompt hemorrhage control some patients may avoid damage control despite significant early physiologic derangement.

b. Abdomen cannot be closed without abdominal hypertension[16]. Excessive fascial tension will often be palpably evident to the surgeon at the time of closure. Bladder pressure may be measured, but is cumbersome in this setting. Peak airway pressure is often measured during fascial approximation, though some data suggests poor correlation with intra-abdominal pressure[24]. Exact cutoff values permitting closure are not known, and judgement and experience should guide the decision to proceed.

c. The patient is at increased risk for postoperative abdominal compartment syndrome (ACS). Even if excessive fascial tension is not present at the time of planned closure, risk of later development of intraabdominal hypertension (IAH) may be unacceptably high. Early IAH may impact important outcomes including survival[24]. Numerous potential risk factors have been described among injured patients as well as other critically ill populations. While there is no universal consensus, the following are likely contributors to abdominal hypertension after injury:

1. Severe shock/resuscitation (hypotension, serum lactate>5, blood loss>4L, transfusion >10u packed red cells) [7,25,26,27]
2. Injuries requiring packing[28,29]

3. Obvious visceral swelling
4. Abdominal wall tissue loss
5. Obesity[26]

d. Additional delayed definitive abdominal procedures (e.g. bowel anastomosis) are required. Even in the absence of abdominal hypertension, fascial closure should be deferred if relaparotomy for further organ repair/debridement is planned. Repeated closing and re-opening of fascia causes unnecessary tissue damage.

e. Non-absorbable intraabdominal packing is used, or temporary devices (e.g. vascular shunts) are left in the abdomen. If the decision is made to manage hemorrhage with packing, a temporary abdominal closure should be used which allows for abdominal swelling without excessive pressure increases. A balance exists between using packs to create local positive pressure/ tamponade, while avoiding compression of major vessels and creation of abdominal hypertension.

f. A second look operation is needed (e.g. marginal bowel viability). Planned reevaluation of marginally perfused bowel or other organs may be appropriate if clear demarcation is not visible, or when abdominal viscera are globally hypoperfused due to shock, making accurate evaluation difficult.

If an indication for damage control does not exist, fascia should be closed primarily at the first operation to avoid the deleterious consequences of the open

abdomen. Many emergent trauma operations (e.g. uncomplicated splenectomy for severe injury with transient hypotension) will not require damage control. Physiology should be continuously reassessed during surgery, and consideration given to primary closure if patient condition improves over the course of the operation. Patients without packing who are easily closed at the second operation may benefit from review for appropriateness of damage control, as part of an institutional continuous quality improvement program [5].

2. Choice of dressing and attention to detail in critical care management have significant impact on outcomes

a. The initial dressing may be a commercial product (e.g. Abthera, KCI), or may be fashioned by the surgeon from available surgical supplies[30–34] . In either event, it should be watertight, and should employ negative pressure to drain abdominal fluid and allow for its measurement. The dressing should be lax enough to allow for abdominal swelling without abdominal hypertension. The layer adjacent to viscera should be smooth and nonadherent. Additional closed suction drains may be placed as part of specific injury management. Primary fascial closure should not be performed in the damage control setting. Temporary closure of skin (e.g. with towel clamps) may put the patient at risk for subsequent abdominal hypertension[35].

b. In the perioperative period, principles of damage control resuscitation should be applied. Fluid balance should be measured carefully, including abdominal losses. Excessive crystalloid should be avoided[36] Diuresis may be useful in selected cases, but routine aggressive diuresis has no demonstrated efficacy[37] . Balanced blood products should be used to correct anemia and coagulopathy, guided by predetermined ratios or laboratory tests/thromboelastography[20] . Intraabdominal pressure should be measured, as IAH or ACS may develop even with an open abdomen.

c. Though evidence is limited, Direct Peritoneal Resuscitation– in which hypertonic peritoneal dialysis solution is instilled into the abdominal cavity in the immediate postoperative period – may lead to increased rates of primary fascial closure, as well as improving other physiologic outcomes. Suggested mechanisms include visceral vasodilatation, reduced organ edema, and decreased cytokine levels[38].

d. There is no consensus on prophylactic antibiotic use in open abdomen patients. When used, antibiotics should be appropriate for injuries, and limited in duration.

e. Appropriately selected patients who pass spontaneous breathing trials may be extubated during open abdomen management[39]. Extubation may be deferred if respiratory mechanics are poor, if there is persistent metabolic acidosis, if intervals between repeat operations are short (<24h), or if a difficult airway is present.

f. Early enteral nutrition should be provided whenever possible. Damage control patients are hypermetabolic and require careful attention to nutritional needs[40] . Historically, many surgeons were concerned that gut function might be ineffective when viscera were exposed, or that early feeding might worsen ileus, which might exacerbate loss of domain. However, subsequent experience and studies have shown that early enteral feeding is feasible[41,42]34.

3. Evidence of good response may include stabilization of vital signs, resolution of metabolic acidosis, improvement of end organ function (mental status, urine output, skin perfusion), or other clinical/laboratory markers. Ongoing, uncontrolled hemorrhage may manifest through high volume sanguineous dressing/drain output, bleeding at external wound site, or falling hemoglobin levels. Continued or accelerated bleeding should prompt surgical re-exploration to search for surgical correctable bleeding sites. In cases of refractory coagulopathic bleeding, re-exploration is often fruitless.

4. Reoperation should take place as soon as possible after adequate resuscitation and correction of metabolic abnormalities. Ideally packs are removed within 24 hours, though timing of removal may depend on the indication for packing and the degree of soiling. Excessive delay in reoperation should especially be avoided in patients with proximal bowel in discontinuity, retained packs/sponges, or intravascular shunts.

5. Patients with prolonged open abdomen may be at added risk for complications including colonic anastomotic leak[43], surgical site infection, fluid loss/metabolic derangement, and failure of primary fascial closure[44]. Colonic anastomotic leak rates have been found to increase with duration of open abdomen, and when more than one relaparotomy is required[45], leading many surgeons to believe that colostomy should be considered if the abdomen is likely to be left open longer than 36 hours, or if multiple relaparotomies are needed. Anastomosis beyond first relaparotomy has been successfully offered by some authors in carefully selected patients[46].

6. Progressive abdominal closure - with eventual primary fascial approximation - may be facilitated by:

a. Continued damage control resuscitation, including judicious management of fluid balance, avoiding excessive crystalloid use

b. Application of negative pressure and continuous tension to abdominal wall, using handmade or commercially available (Wittman patch, Abthera, e.g.) devices[4731,48–50]. Continuous negative pressure and retention sutures both provide fascial tension, and may be used together[51,52]

c. Progressive sequential closure of fascial edges starting at each end of fascial incision[51]. Typically, patients return to OR every 2 days for further closure.

c. Periodic readjustment of tensioning device, either at bedside or in operating room.

7. Progressive primary closure should be abandoned when there is lack of progress upon attempts at re-tensioning, or when duration of open abdomen becomes prolonged (e.g.7-10 days). Further attempts at re-exploration and closure are associated with diminishing likelihood of fascial closure [53]may put the patient at risk for bowel injury, fistula development, or septic complications[54,55]

Alternative abdominal closure techniques include:

a. Placement of permanent, bridging prosthetic or bioprosthetic mesh. A full discussion of mesh choices is beyond the scope of this document, but simple first generation, wide-pore polypropylene mesh (e.g. Marlex®, Prolene®) is prone to erosion into intestine, and should not be used directly adjacent to bowel. However, a wide and evolving variety of composite meshes are available with nonerosive layers for contact with bowel[56]. Bioprosthetics are less prone to erosion, but are associated with high eventration rates when used as a bridge[57].

b. Placement of absorbable mesh such as Vicryl® (Polyglactin 910), with or without skin closure or interval split thickness skin grafting

c. Skin only closure. Running or interrupted technique may be used. Local skin complications such as necrosis at suture entry sites are common, but rarely catastrophic.

d. Complex free/rotational flap closure (typically in cases of massive loss of abdominal wall soft tissue). Choice of flap depends on size, and other injuries at potential donor sites.

e. Components separation during initial admission has been described [58] but is more commonly avoided, allowing for use in later elective abdominal wall reconstruction.

Figure 2

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Figure Legend

Figure 1: Process for creation of WTA Critical Decision Algorithm

Figure 2: WTA Algorithm: Management of Open Abdomen after Damage Control