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Bedside diagnostic laparoscopy and peritoneal lavage in the intensive care unit

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Abstract
Background: Early diagnosis and treatment of intra-abdominal pathology in critically ill intensive care unit (ICU) patients remains a clinical challenge. The objective of this study is to assess the feasibility of portable, bedside diagnostic laparoscopy (DL) in the ICU for patients suspected of intra-abdominal pathology, and to contrast its accuracy with diagnostic peritoneal lavage (DPL).
Methods: All adult ICU patients for whom a general surgery consultation was requested were eligible. Patients with a recent laparotomy or obvious peritonitis were excluded. All procedures were performed in the ICU.
Results: Over a consecutive 16-month period, 12 patients underwent DPL/DL. Ages ranged from 28 to 88 (mean, 72) years. Causative findings were disclosed by DL in five patients, (42%) including intestinal ischemia in two. Perforated diverticulitis, thickened terminal ileum, and nonpurulent peritonitis were found in one patient each. All patients with findings by DL had a positive DPL (WBC > 200 cells/mm^3), and one negative laparoscopy was positive by lavage. The average length of time to perform DPL was 14 min, and to complete DL 19 min. One patient underwent laparotomy based on DPL/DL and survived along with three others with negative DPL/DL. Eight patients died (67%), four from their surgically untreated intra-abdominal pathology. One patient sustained a procedure-related complication of bradycardia and high ventilatory airway pressures. Peak airway pressures increased an average of 8 mmHg and were significantly higher ($p < 0.001$) than pre-DL pressures without any significant change in end-tidal CO_2 or pCO_2. There were no statistically significant hemodynamic changes based on mean arterial pressure (MAP), central venous pressure (CVP), or pulmonary artery diastolic pressure (PADP).
Conclusions: Bedside laparoscopy can be performed rapidly and safely in the ICU. In predicting the need for laparotomy, DL was more accurate than DPL.

Key words: Diagnostic laparoscopy — Critical care — Diagnostic lavage — Bedside laparoscopy — Hemodynamic/ventilatory — Complications of laparoscopy

Early diagnosis and treatment of intra-abdominal pathology in the critically ill intensive care unit (ICU) patient remains a clinical challenge. Multiple factors affect the reliability of a clinical assessment including pharmacologic or metabolic obtundation, prior intubation, and compounding comorbid medical conditions. The manifestations of intra-abdominal pathology may also be altered in the elderly and immunocompromised patients who reside in the medical ICU [21, 27]. A surgical consultation may thus be required for unexplained sepsis, acidosis, and multisystem organ failure (MSOF). In patients who are difficult to transport and unstable, diagnostic radiologic studies are not easily obtained or interpreted [1, 10, 18]. The mortality of laparotomy for recognized abdominal pathology exceeds 25% [8, 26], which has prompted a recommendation for early laparotomy in all patients with unexplained MSOF [9].

Laparoscopy allows for direct intra-abdominal visualization, which has altered structures affecting management decisions in ambulatory patients with acute abdominal pain [15, 20, 23, 24]. The direct application of laparoscopy in the ICU has been described infrequently, but it offers the potential for expedient and accurate evaluation of suspected intra-abdominal pathology [5, 11].

Diagnostic peritoneal lavage (DPL) is another invasive diagnostic procedure that has been applied to patients with a suspected acute abdomen [2, 13, 16]. Its advantages include rapid assessment by cell count and gram stain of the effluent without the need for pneumoperitoneum or expen-

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sive equipment. Although sensitive in detecting the presence of inflammation, DPL is nonspecific in determining etiology. The purpose of this study was to prospectively determine the accuracy and complications of bedside laparoscopy in the ICU and compare its specificity with the results of DPL in guiding patient management.

Methods

Since January 1, 1994 all adult patients in the ICU for whom a surgical consultation was obtained to evaluate an acute abdomen were considered eligible. Patients had been previously admitted to one of the medical, cardiac, cardiothoracic, or surgical intensive care units. Note was made of the patient's ICU diagnosis on admittance and the criteria used to determining the presence of organ system failure as previously defined [6, 26]. Informed consent was obtained from the next of kin or legal guardian. Patients were considered ineligible for the study if laparotomy was required for generalized peritonitis or free intra-abdominal air, if there had been a previous laparotomy within 30 days, if signs of intestinal obstruction were present, if there was uncorrectable hypercapnia greater than 50 Torr, or if the attending surgeon's discretion contraindicated inclusion.

An anesthesiologist directed hemodynamic monitoring, ventilation, and administration of total intravenous anesthesia. Patients were induced with propofol (1–1.5 mg/kg) and fentanyl (1–2 μg/kg), and maintained with a propofol infusion (30–80 μg/kg/min) and additional 25–50-μg increments of fentanyl as required. All patients not previously intubated underwent oral endotracheal intubation, which was facilitated by atracurium (0.5 mg/kg) at the time of induction. Mechanical respiration was supplied by either a Puritan-Bennett 7200 (Puritan-Bennett, Carlsbad, CA) or a Servo 900C or 300 (Siemens-Elema, Solna, Sweden) ventilator with an F_1O_2 of 1.0 and a flow-limited, volume-controlled mode.

In patients who were mechanically ventilated before enrollment in the study, minute ventilation was increased 120 to 125% of that ordered by the primary physician and held constant throughout the procedure. Analgesia was achieved with lidocaine 1% (Abbott Laboratories, North Chicago) infiltration of the skin and subcutaneous tissues at all trocar sites. Extubation after the procedure was determined by the results of laparoscopy and the patients' preexisting medical condition.

All patients underwent DPL followed by diagnostic laparoscopy (DL). All procedures were performed in the ICU under sterile conditions by a surgeon and one assistant. An open technique was used to enter the abdomen by an infraumbilical incision. After the abdomen was entered, a 42-cm straight Tenckhoff catheter (Quinton Co, Seattle) was directed toward the pelvis and 1 liter of normal saline infused. Return flow was established with gravity drainage until a minimum of 500 ml were collected. The effluent was sent for gram stain, cell count, and determination of amylase levels. A positive lavage was defined as a white blood cell (WBC) count of more than 200 cells/mm^3, which would constitute the need for laparotomy [16]. The length of time from the incision to the removal of the peritoneal catheter was recorded.

Diagnostic laparoscopy was performed immediately after the completion of DPL. A 10–11-mm Hassan cannula was placed at the infraumbilical site previously used for lavage, and the abdomen was insufflated with CO_2 to 15 mmHg with a pressure-controlled insufflator (Wolf Inc, Rosemont, IL). The insufflator was stored on a designated mobile cart, which also included a 12-inch Sony trinitron video monitor (Ichinomiya, Japan), Olympus CLK-4 halogen light source (Success, NY), and CCD video camera (Elmo Co. Ltd.). Also available from this cart were sterile drapes, 5- and 10-mm trocars, laparoscopic retractors, and instruments to perform a complete examination. A minor laparotomy tray, zero-degree telescope, and light cord were kept sterile in central surgical supply and made available for each procedure. After creation of the pneumoperitoneum, additional 5-mm trocars were placed under direct visualization as needed to completely view the anterior surface of the stomach, entire small intestine and colon, gallbladder, and liver. Hemodynamic and ventilatory parameters were assessed before and throughout the laparoscopic procedure. When available, these included measures of mean arterial pressure (MAP), pulmonary artery diastolic pressure (PADP), central venous pressure (CVP), peak airway pressure, end-tidal CO_2, pH, and pCO_2. All data parameters were compared before and after laparoscopy with statistical significance determined by paired t test or Wilcoxon's signed-rank test with $p < 0.05$ considered significant.

Results

During a consecutive 16-month period, 12 patients underwent DPL/DL. This represented approximately 2% of all patients consulted for an acute abdomen in 6,089 patients admitted to 110 ICU beds. The participants included nine men and three women with a mean age of 72 (range, 28 to 88) years. All 12 patients had been admitted to the ICU with diagnoses not originally thought to be of an intra-abdominal origin, including pulmonary failure with adult respiratory distress syndrome (ARDS) in four patients, sepsis syndrome in four (one post-CABG), cardiogenic shock in three, and acute aortic occlusion in one. The length of stay in the ICU to the time of surgical consultation ranged from 12 hours to 28 days, with eight patients evaluated within 48 hours of ICU admission. All patients received nondiagnostic plain radiographs of the abdomen. Eight patients also received a computed tomography (CT) and/or ultrasound scan. Four of these patients were thought to have an abnormal gallbladder on the basis of distension, wall thickening, and/or sludge.

The mean acute physiology and chronic health evaluation (APACHE) III [14] score for these patients on ICU admission was 97 (range, 56 to 141), with a mean predicted mortality of 54% (range, 5 to 93%). All patients had been intubated, and each had failure of at least one organ system; renal, pulmonary, cardiac, and/or hepatic. Hypothermia (temperature < 34.5°C) was present in five patients, pyrexia (temperature > 38.5°C) in four, and normothermia in three. Leukocytosis ranged from 12 to 33 (mean, 21) K/UL. Eight patients (67%) were hypotensive (SBP ≤90 mmHg) at some time within 24 hours of DPL/DL. Half of the patients (six) had no prior abdominal operations; four had one prior laparotomy; and two patients had two and three laparotomies, respectively.

The findings of DPL/DL and outcomes are summarized in Table 1. Peritoneal lavage was successfully accomplished at a mean time of 14 (range, 3–25) min. The average volume fluid returned was 575 ml. Six patients had a positive DPL based on cell count, and one of these also had organisms observed on gram stain. There were no complications attributed to the performance of DPL.

Time required for laparoscopy averaged 19 (range, 8–40) min. All but one patient required one additional trocar to obtain a satisfactory inspection, and none required more than one extra trocar. Specific intra-abdominal pathology was found in five patients, who were also found to have a positive lavage. These findings included intestinal ischemia in two patients, perforated diverticulitis in one, nonpurulent peritonitis in one, and a thickened terminal ileum in one. One patient with a positive lavage had a negative laparoscopy performed within 12 hours of ICU admission and was spared laparotomy. This patient was later diagnosed with *Clostridium difficile* colitis by toxin assay and rapidly succumbed to septic complications of *Pseudomonas aeruginosa* aspiration pneumonia and candidemia. None of the patients with an abnormal biliary ultrasound were found to have cholecystitis. One patient sustained a DL-related com-

Table 1. Patient characteristics and results

Patient	ICU admitting DX	Time in ICU	Lavage (WBC/mm^3)	DPL (min)	DL (min)	Laparoscopy findings	Outcome
1	Myocardial infarction	5 days	619	25	30	Intestinal ischemia	No laparotomy, death
2	Cardiac arrest	12 h	15	17	15	None	Survived
3	Pulmonary failure	12 h	30,900	8	12	Sigmoid diverticulitis	No laparotomy, death
4	Septic shock	48 h	536	18	40	Thickened terminal ileum	Ileum resected, survived
5	ARDS	7 days	10	20	20	None	Death
6	Septic shock	24 h	10,900	5	20	Intestinal ischemia	No laparotomy, death
7	Sepsis	28 h	37	17	8	None	Survived
8	Pneumonia	24 h	16	10	15	None	Death
9	Cardiogenic shock	48 h	17	12	15	None	Death
10	Aortic occlusion	24 h	135	12	15	None	Survived
11	Aspiration pneumonia	12 h	593	3	15	None	Death
12	CABG	26 days	5,565	18	20	Nonpurulent peritonitis	No laparotomy, death

CABG, coronary artery bypass grafting.

plication of bradycardia and transient peak airway of 65 mmHg, which resolved promptly with release of the pneumoperitoneum. This patient had the longest DL at 40 min and was the only patient with an incomplete examination with failure to visualize the gallbladder. Ventilatory and hemodynamic parameters during DL are summarized in Table 2. There were no adverse hemodynamic changes in the entire group as determined by MAP, CVP, or PADP. Peak airway pressures increased an average of 9 mmHg (range, 1–23), which was a significant change compared with pre-DL ($p < 0.001$) pressures. There were no associated significant changes in end-tidal CO_2 or pCO_2. There were no pneumothoraxes or CO_2 emboli.

One patient underwent laparotomy based on the DPL/DL results that involved resection of his gallbladder, terminal ileum, and right colon for previously undiagnosed Crohn's disease in a setting of *Clostridium perfringes* septicemia. This patient survived along with three others with negative DPL/DL. Eight patients died (67%), four from their untreated intra-abdominal pathology diagnosed by DL after discussions with the family. The other four patients died from ongoing multisystem organ failure, one four days after DPL/DL and the other three after more than two weeks. No autopsies were performed per family requests.

Discussion

Bedside laparoscopy in the ICU has been shown to offer safe and accurate evaluation of the abdomen that can directly affect patient management. This advantage was accomplished in a small, but difficult to manage group of patients who were gravely ill with MSOF and nonspecific abdominal findings. Previous reports involving a total of 42 patients are notable for describing DL performed in the operating room [3, 4], and for failing to identify the number of patients who may be potential candidates for the procedure. These studies do highlight the value of DL in directing management with 21 of 42 patients found to have pathology requiring laparotomy and avoiding a nontherapeutic laparotomy in the others [3, 4, 11].

In our cohort of 12 patients, five were found to have life-threatening intra-abdominal pathology, which had a direct impacted on their management, and seven successfully avoided unnecessary laparotomy. This information was gained expediently in 75% of our patients within 48 hours of admission to the ICU without transport to an operating room and often without advanced and expensive radiologic studies. The ease and safety of bedside DL may result in early recognition of surgical pathology and ultimately have an impact on survival as anticipated with early laparotomy for similar patients [9]. Expedient intervention may also have a large economic impact by reducing other diagnostic testing and surgical complications. Although eight patients died, there were no deaths due to the performance of DL, and one patient underwent operation on the basis of previously known intra-abdominal sepsis and survived. On the basis of our findings, we recommend prompt bedside DL in ICU patients with an unexplained septic syndrome, MSOF, or gram-negative bacteremia.

The presence of sophisticated monitoring equipment in the ICU makes it safe to perform DL there. The brevity of the procedure is reflected in the lack of adverse hemodynamic changes due to pneumoperitoneum in these unstable patients, 67% of which were hypotensive within 24 hours of the DL. Experimental data would have predicted a decrease in cardiac output to less than 80% of baseline after 20 min of insufflation [28]. Ventilatory considerations predominate in these critically ill patients undergoing peritoneal insufflation. Significant hypercarbia with subsequent respiratory acidosis can occur in these patients within 15 min of CO_2

Table 2. Ventilatory and hemodynamic changes with laparoscopy

	CVP	PADP	MAP	Airway pressure	pH	CO_2	End-tidal
Prelaparoscopy	13.0 ± 4.9	19.7 ± 6.0	75.9 ± 14.0	32.1 ± 4.9	7.40 ± 0.05	30.0 ± 7.87	27.1 ± 9.9
Postlaparoscopy	13.9 ± 4.6	18.9 ± 4.7	76.8 ± 9.0	40.0 ± 10.2	7.37 ± 0.07	32.4 ± 11.6	26.4 ± 8.5
Change	0.9 ± 3.1	−0.8 ± 2.6	0.9 ± 8.7	7.9 ± 7.4	−0.02 ± 0.07	2.4 ± 7.1	−0.7 ± 5.0
p Value	0.35	0.84	0.72	<0.001	0.25	0.25	0.97

All values are expressed as means ± standard deviations. CVP, central venous pressure (cm H_2O); PADP, pulmonary artery diastolic pressure (mmHg); MAP, mean arterial pressure (mmHg); Airway pressure, peak pressure (mmHg); pCO_2, arterial partial pressure CO_2 (Torr); Endtidal, continuous capnometry.

insufflation due to an increased dead space [29]. Hypercarbia is most often due to peritoneal absorption of CO_2 even in the presence of hypotension, resulting in a 30% increase in CO_2 production, which remains constant for procedures lasting longer than 15 min [17, 22]. The anticipated changes in CO_2 production can be compensated for by placing all of these patients on controlled ventilation with increased minute volumes as performed in our cohort [7, 25]. Critical changes in pCO_2 and pH are best monitored with arterial blood gasses, and potentially by continuous capnometry [12, 19]. Discrepancies between pCO_2 and end-tidal CO_2 determinations should be anticipated with changes in the arterial to end-tidal gradient in patients with increased ventilation-perfusion mismatches undergoing peritoneal insufflation [19]. Although no significant changes in pCO_2 and pH were encountered, a significant increase in peak airway pressures was noted, which likely contributed to bradycardia in one patient. Changes in airway pressures [28] are directly correlated with intra-abdominal pressures and should encourage low-pressure insufflation for preexisting elevated airway pressures.

Diagnostic peritoneal lavage, as shown by other authors, is accurate in diagnosing the presence of peritonitis and a potential adjunct in ICU patients [2, 13, 16]. In our series of patients, it was not as accurate as DL in determining the presence of intra-abdominal pathology. One patient with *C. difficile* colitis and positive lavage was found by cell count to have a negative gram stain and culture and by DL a normal colon and thus did not require laparotomy. Laparotomy would have been recommended in the other five subjects on the basis of the lavage results, and abdominal pathology would have been identified. In the majority of patients, DPL lacks specificity in regard to etiology, which can be clearly established by DL without laparotomy. The fact that it was possible to avoid laparotomy five patients despite a positive DPL speaks to the value of identifying a specific etiology and not simply the presence of intra-abdominal pathology.

Conclusions

Bedside diagnostic laparoscopy has been proved accurate in diagnosing intra-abdominal pathology and is valuable in directing further patient management. It can be performed safely in the ICU setting without serious hemodynamic or ventilatory consequences. By achieving the direct visualization of the type and extent of pathology, DL exceeds a positive DPL in its valve for directing patient management.

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