The Accuracy of Diagnostic Peritoneal Lavage in Penetrating Abdominal Trauma

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ABSTRACT

Background. Penetrating abdominal injuries without clear indications for laparotomy are a dilemma for surgeons. Delayed celiotomy increases the morbidity and mortality while unnecessary laparotomies are inefficient. Diagnostic peritoneal lavage (DPL) is re-explored to determine its accuracy in penetrating abdominal trauma.

Methods. All adult patients with penetrating abdominal injuries without indications for laparotomy at the Philippine General Hospital from September 1999 to March 2001 were included in the study. All underwent DPL and standard management in monitoring for penetrating abdominal injuries and await indications for laparotomy. Using various cut-offs for lavage red blood cell count (LRBC) as criteria in interpreting DPL results and, using either intraoperative findings or follow-up patient examination findings (for those who were not operated on) as gold standard, measures of accuracy were estimated. Receiver operating curves (ROC) were generated using various cut-offs and the most clinically acceptable criteria (cut-offs) were selected.

Results. Of the 213 cases, 69% were operated on and the rest were followed up for 2 weeks to determine if there were significant intra-abdominal injuries. The ideal cut-off for LRBC count was ≥5,000/cu mm (≥5000/cu mm as positive and <5,000/cu mm as negative) with a sensitivity of 93.2% (95% CI: 87.2, 96.7), specificity of 87.5% (95% CI: 77.8, 93.5) and a false positive rate of 12.5%. LWBC count showed no correlation to significant injuries.

Conclusions. DPL may be utilized as part of the selective management of penetrating abdominal injuries without clear indications for laparotomy. Using the LRBC count criterion of 5,000/cu mm, sensitivity is high and the false positive rate is acceptable.

Key Words: diagnostic peritoneal lavage, penetrating abdominal injury, accuracy, laparotomy

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Introduction

Penetrating injury to the abdomen and lower chest, either by stab wound or gunshot wound, is still the most common indication for admission and surgery for trauma in the Philippine General Hospital at 65.4% in the year 2000.[1]

Military experience no doubt perpetuated the mandatory exploration policy in civilian practice. Following World War II, Jarvis et al.[2] and Rob[3] ascribed increased mortality to unnecessary laparotomy, but the concept of selective exploration for penetrating abdominal trauma was largely ignored until the classic report of Shaftan in 1960, which pointed out the difference between military and civilian wounds and established the safety of selective exploration based on physical signs and peritoneal lavage.[4]

A local retrospective study of 127 cases from the Jose R. Reyes Memorial Medical Center (another tertiary care hospital in Metro-Manila), described the center's experience in the selective management of solitary stab wounds to the abdomen. Salcedo and Herbosa[5] reported a 9% (95% CI: 4.4–15.0) negative exploration rate (non-therapeutic laparotomy rate) when only physical examination was used to decide which patients would warrant surgery. The negative exploration rate may seem low compared with that reported by Shorr and his co-workers, but it should be noted that in the local report only solitary injuries were included. Furthermore, with a 95% confidence interval of 4.4% to 15%, this is very close to the 14.3% reported by Shorr.[6]

If peritoneal violation is proven or suspected, the next step is to determine if visceral damage has resulted from the penetration. With few exceptions most authorities now rely on diagnostic peritoneal lavage (DPL) for this purpose.[7] Ryzoff et al.[8] were the first to employ abdominal paracentesis in the evaluation of penetrating trauma. Root et al.[9] improved the sensitivity of this test by adding peritoneal lavage to the simple aspiration procedure. An initial aspiration of more than 10 ml of gross blood or fluid containing bile, bacteria, or particulate matter is an undisputed indication for celiotomy. If the aspirate findings are negative, 1 liter of normal saline (15ml/kg BW in children) is infused. The lavage red blood cell (LRBC) count concentration is the best indicator for celiotomy.[10,11,12,13] The minimum LRBC count, however, remains an unsettled issue (Table 1).

Table 1. Sensitivity and Specificity of Lavage Red Blood Cell (LRBC) Count in different studies utilizing different cut-offs

Study	Institution	n	Lavage RBC Cut-off	Sensitivity (95% CI)	Specificity (95% CI)
Root, et al	Univ.of Minnesotta	28	≥100,000/cu mm	100% (79 to 100)	100% (74 to 100)
Hornyak	King's County Hospital Center, NY	30	≥20,000/cu mm	42.9% (23 to 66)	67% (31 to 91)
			≥50,000/cu mm	24% (10 to 47)	89% (51 to 99)
Oreskovich	Harbourview Medical Center, WA	236	≥1,000/cu mm	100% (97 to 100)	55% (46 to 64)
			≥50,000/cu mm	70% (60 to 78)	94% (88 to 97)
			≥100,000/cu mm	59% (50 to 68)	97% (91 to 99)
Feliciano	Ben Taub Gen. Hospital, TX	500	≥100,000/cu mm	95% (89 to 98)	94% (90 to 96)
Henneman	Denver General Hospital and UCLA	336	≥100,000/cu mm	87% (76 to 96)	89% (82 to 97)

In an unpublished review of cases, 993 patients diagnosed to have penetrating abdominal injuries admitted at the Philippine General Hospital were identified.[14] Ninety-three patients (10%) initially presented without indications for laparotomy. A negative laparotomy rate was seen in 60 patients (6.4%). The operative mortality (number of mortalities/number of patients operated) was 5.35% and the operative morbidity rate was 13% (surgical site infection, wound dehiscence, and hospital acquired pneumonia).

With this profile of patients, together with the present unreliability of physical examination and diagnostic tests, plus the absence of an acceptable criteria in the interpretation of DPL results, the dilemma of evaluating patients with penetrating abdominal injuries without clear indications for laparotomy is brought to fore.

At the Division of Trauma of the Department of Surgery of the Philippine General Hospital, the author aims to evaluate the accuracy of DPL in patients with penetrating abdominal injuries, presenting without indications for laparotomy, using varying cut-off levels for LRBC and/or lavage white blood cell (LWBC) count, to identify significant intraperitoneal injuries that warrant surgical intervention.

Methods

From September 1, 1999 to March 15, 2001, all adult patients with penetrating injuries to the abdomen, without clear indications for laparotomy, at the Philippine General Hospital, were included in a prospective study. Those with concomitant injuries to the CNS, skeletal system, burns or skin loss in the torso were excluded. Patients with a history of previous laparotomy or under the influence of alcohol or other medications that may preclude a proper physical examination were also excluded.

DPL was performed by the senior surgical resident. The open technique described by Moore in the textbook *Trauma*[15] was used. For ethical reasons, the Division of Trauma, in agreement with the author, set an arbitrary cut-off of 5,000 RBC/cu mm, the lowest cut-off reported in literature,[11,12] as the LRBC cut-off to mandate exploratory laparotomy. Those with overt intraluminal contents seen in the lavage fluid (e.g., food particles, feces, bile, sucus entericus) likewise underwent laparotomy.

The standard preoperative management for patients with penetrating injuries to the anterior abdomen was carried out in all patients. Presumptive antibiotic therapy was given to all patients for 24 hours and continued for 7 days when the results of the exploration were positive. This was discontinued if the exploration turned out to be negative or surgery was not performed. Analgesics were given as needed. In the absence of any indication for laparotomy after 24 hours, the patient was discharged with instructions to follow up weekly for 2 weeks, and to proceed to the hospital for any undue developments (e.g., fever, vomiting, abdominal distention, bleeding, wound disruption).

Two main variables were investigated: DPL (the test) results and intraoperative findings or findings on follow-up (the gold standard). Various cut-offs for the LRBC count and the LWBC count were set to determine positivity of the test. Although the lavage fluid samples were examined by different medical technologists, the author believes that inter-observer and intra-observer variability will be minimized by the technicians following a standard procedure for preparation and counting of the cells found in the samples. Using intraoperative results or OPD follow-up results (for those not operated) as the standard to determine the need for surgery, the software Two by Two and MetaDx were used to calculate accuracy while utilizing the various cut-offs.

The sensitivity and specificity of each of the models were estimated at a 95% confidence interval. Positive and negative predictive values were calculated. Receiver operating curves were constructed, plotting the sensitivity values against the false positive rates of the different cut-offs and the curve was analyzed to determine the most appropriate model for cut-off for LRBC and LWBC count.

To estimate sample size, the values 95% and 90% were used for the sensitivity and specificity. The prevalence rate of this subset of patients, as estimated from the review of cases for 1994, was 30 to 40%. Setting the precision to 0.05 and f (1-a) at 3.842 (equivalent to a 95% confidence interval), with a sensitivity of 95% and a prevalence of 30%, the sample size was calculated at 243.

Results

Ninety-two percent (92%, 196, n=213) of the sample were males. The mean age was 30 years (range: 15 to 84 years) (Table 2). Sixty-two percent (62%, 133) of these patients without any indications for laparotomy turned out to have significant intra-abdominal injuries. Seventy percent (70%, 150) of the 213 patients were operated on. The overall negative laparotomy rate was 11.3%. It is interesting to note that in the 50 patients who were operated on due to the LRBC indication alone, the negative exploration rate was only 6% (3 out of the 50) (Table 3).

Table 2. Age and Sex Distribution of the 213 cases

n	Age Range	Mean Age	Standard Deviation	p - value
Overall	213	15 to 84	10.5	
Male	196	15 to 84	10.4	0.56
Female	17	15 to 63	11.7	

Table 3. Distribution of cases according to significant intra-operative findings

Intra-operative findings	n	%
No exploration	63	29.6
Negative exploration	17	8
With significant findings	133	62.4
Total	213	100

Most of the penetrating injuries (91%) were due to stab wounds and only 6.6% were due to gunshot wounds. The incidence of significant intra-abdominal injuries in those with stab wounds and those with gunshot wounds were comparable (p = 0.64) (Table 4).

Table 4. Distribution of cases according to type of injury

Type of Injury	n	%
Stab Wounds	194	91.1
Gunshot Wounds	14	6.6
Puncture (Ice Pick)	4	1.9
Grenade	1	0.5
Total	213	100

Lavage red blood cell (LRBC) count. A receiver operating curve was constructed plotting the various sensitivity rates against the false positive rates of the different models using various cut-offs for LRBC count (Figure 1). This showed the ideal model to be at either the LRBC count cut-offs set at 5,000/cu mm or 10,000/cu mm. With the cut-off set at 5,000/cu mm of LRBC, sensitivity was 93% (95% CI: 87.2, 96.7) and specificity was 88% (95% CI: 77.8, 93.5) corresponding to a false positive rate of 12.5%. Ten out of 213 were operated on but did not have significant intra-abdominal injuries. With the cut-off set at ≥10,000/cu mm of LRBC, sensitivity was 91% (95% CI: 82.5, 95.3) and specificity was 93% (95% CI: 81.9, 97.7). Eight out of the 213 cases were operated on but did not have significant intra-abdominal injuries.

On the other hand, using the same criterion (cut-off of 5,000/cu mm) in patients who had their DPL done after 6 hours post-injury, the sensitivity was decreased at 86% (95% CI: 78, 90) and specificity was 75% (95% CI: 67, 83) while increasing the false positive rate to 25% (Figure 2).

Lavage white blood cell (LWBC) count. Using LWBC count as criteria in determining significant intra-abdominal injury in patients with penetrating abdominal injuries presenting without indications for laparotomy was disappointing. Neither a clear and ideal nor an acceptable model could be identified on examination of the receiver operating curve constructed for LWBC count (Figure 3).

Patient follow-up. The follow-up period was 2 weeks and in the two visits (weekly) the patients had to comply with, the attendance was 100%. Only one morbidity was detected (morbidity rate: 1/213, 0.4%, 95% CI: 0, 2.6), a superficial surgical site infection which caused a wound dehiscence during the 7th hospital day. This patient underwent an exploratory laparotomy only for closure of the abdominal wound. There were no mortalities and no complications directly attributable to the DPL detected (mortality rate: 0/213, 0%, 95% CI: 0, 1.6%).

Discussion

The main objection to the use of DPL in penetrating abdominal injury is that there is no universally accepted LRBC count that characterizes the DPL as positive.[16] However, the reported sensitivity values have been encouraging, ranging from 87 to 100%.[9,17-19] The primary consideration should be a diagnostic test that has the highest sensitivity. The trade-off naturally would be a decrease in specificity; it would therefore be important to monitor if the resulting false positive rate is acceptable to the clinician.

In this study, the cut-off for LRBC with the highest sensitivity of 93% (95% CI: 87, 97), specificity of 88% (95% CI: 79, 95), coupled with an acceptable false positive rate of 12%, is ≥5,000/ cu mm. This was selected over the cut off of ≥10,000/cu mm with a lower sensitivity of 90% (95% CI: 84, 95), slightly higher specificity of 90% (81, 95), and lower false positive rate of 10%. The author believes that clinically, in patients with penetrating injuries to the abdomen, it would be more acceptable to perform an unnecessary laparotomy rather than not to operate on a patient with significant intra-abdominal injury.

Definite cut-offs as criteria to help shift management from one direction to another are very important in clinical practice. The author avoided calculating for multilevel likelihood ratios for LRBC and LWBC precisely because an intermediate evaluation (an LRBC count between 5,000 to 10,000/cu mm, for example) will not help the surgeon decide if a laparotomy is indicated or not, and may delay an emergent procedure. This was the problem with the evaluation of LRBC count for blunt abdominal trauma as suggested by Thal and his coworkers.[20] The intermediate

count of 50,000 to 100,000 LRBC/cu mm was not useful clinically and only left the surgeon in a bind if he should do a laparotomy or transfer the patient back to the ward for less intensive monitoring.

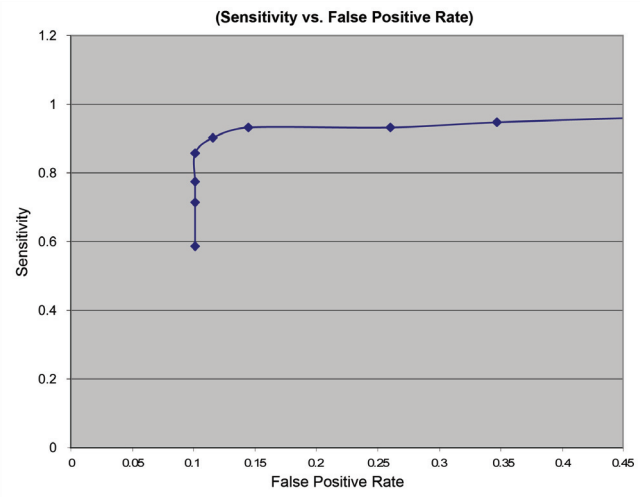

Figure 1. Receiver Operating Curve for LRBC

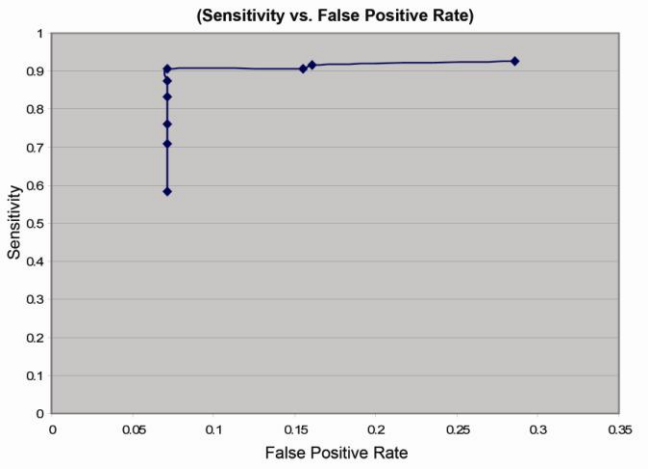

Figure 2. Receiver Operating Curve for LRBC taken ≤ 6 hours Post-injury

The only factor suggested in this study that decreased the false positive rate while maintaining a high sensitivity for DPL was the timing of the lavage. However, this was true only for LRBC. When the lavage was done on or before 6 hours post-injury, the sensitivity was 91% (95% CI: 82, 93) and the specificity 93% (95% CI: 82, 98), corresponding with a better false positive rate of 7%.

Understandably, and as pointed out in the canine studies of Root and his coworkers, even just a small amount of blood will induce some inflammatory reaction in the peritoneal cavity.[21] He reported a two-hour delay for leukocytosis in the peritoneal fluid. This, however, was not seen in this study. No trend could be discerned when LWBC was used. Logically, if there is intra-abdominal bleeding, LRBC count within the peritoneal cavity will immediately increase, and therefore the LRBC count as a variable will be more sensitive compared to an increase in the LWBC count, which will depend on the amount of leukocytic reaction within the peritoneal cavity at the time the DPL is performed.

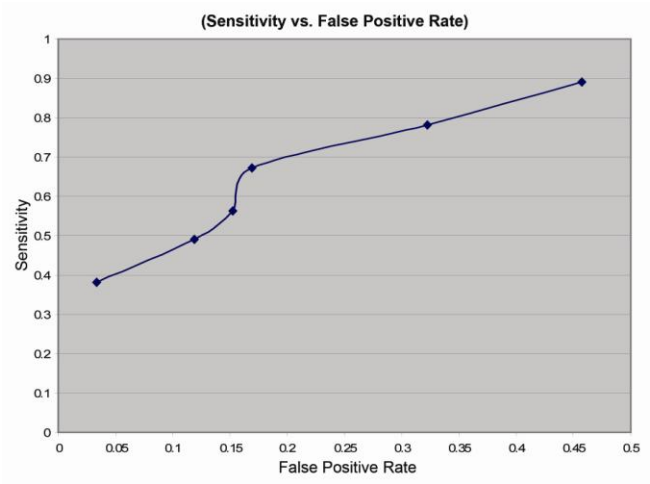

Figure 3. Receiver Operating Curve for LWBC

Similar to data from other institutions, setting the LWBC criterion to indicate significant intra-abdominal injury proved to be disappointing.[8-10,19,22-23] This inconsistent response to intra-abdominal injury may be explained by the fact that the most frequently injured organ in this study was the liver, followed by the small bowel. Root and his coworkers reported that the reaction of the peritoneum was less if the injury was in the small bowel or the solid organs (except the pancreas) compared to injuries to the colon.[21] Interestingly, those with positive findings on laparotomy had the highest mean LWBC count (539.16/cu mm) while those who were explored due to physical findings of peritoneal irritation had a higher mean LWBC count (317.91/cu mm) than those who were not explored at all (18.06/cu mm).

Of interest also to the clinician are the findings on presentation that may help in considering the probability of intra-peritoneal injury. Gunshot wounds, for example, had been cautiously excluded in most selective management applications in the belief that these cases need a more aggressive approach.[24,25] More consistent with the study of Demetriades,[26] this paper showed that the possibility of intra-abdominal injuries in gunshot wounds (57.14%) may not be different from stab wounds (63.4%, $p < 0.05$). However, translating the 6% difference clinically may present a different picture. Moreover, the number of patients with wounds secondary to gunshot is too small compared

with those due to stab wounds (14 against 194) to make a convincing conclusion (Table 4).

In this study, penetration was not verified for gunshot wounds, multiple stab wounds, puncture (ice pick injury), or shrapnel injuries because of the inherent difficulties of verifying penetration. In those with multiple injuries, the problem of verification is magnified. Obviously, there was a limit in the number of wounds we could explore in this manner. For this reason, the Division of Trauma of the PGH made it a policy not to verify penetration in these cases and just presume penetration, and manage the patients as such.

Another consideration is presentation with omental prolapse. The rate of positive findings in those with omental prolapse was 87%, compared with 60% in those without omental prolapse. This was not statistically significant (p=0.17541). However, the author feels that the 27% magnitude may be clinically significant and therefore a more aggressive approach in patients who present with this finding may be warranted. Again, the number of those who presented with omental prolapse is too small to make a strong recommendation (Table 5). This relationship can be further explored in future studies.

Table 5. Omental prolapse and significant intra-abdominal injuries

	n	Significant Intra-abdominal Injuries		
		Positive (%)	Negative (%)	p-value
With omental prolapse	15	13 (86.7)	2 (13.3)	0.11
Without omental prolapse	198	119 (60)	79 (39.9)	

With no patient drop-outs (i.e., 100% follow-up), the ideal sample size would have been 243. Due to the trend of the receiver operating curves (ROC), subject accrual was deemed sufficient at 213 patients, well over the estimated sample size if a specificity of 90% is used and just slightly lower than the 243 required to estimate the sensitivity with reasonable precision.

One case of superficial surgical site infection which led to wound dehiscence was reported. This resulted in a morbidity rate of 0.4% (95% CI: 0, 2.6) associated with a maximum sensitivity of 93% (95% CI: 0.87, 0.97) and specificity of 88% (95% CI: 0.78, 0.94). This morbidity rate is acceptable in light of the high sensitivity and specificity. Moreover, if only to detect potentially serious intra-abdominal injuries early to implement appropriate surgical intervention promptly, a risk of only 0.4% should be very acceptable. No mortalities were detected in the 2-week follow-up in our subject population.

Although not found in the literature search performed by the author, several factors may affect the internal validity and ultimately the external validity of the findings of this study (e.g., bloody dissections, unavailability of epinephrine in some emergency or trauma care units, improper positioning of the lavage catheter, patient obesity).

Conclusions

Diagnostic peritoneal lavage (DPL) may be used to aid the surgeon in the selective management of adult patients presenting with penetrating abdominal injuries initially without indications for laparotomy. Using the most appropriate criterion of lavage red blood cell (LRBC) count of greater than or equal to 5,000/cu mm in these patients, the sensitivity is 93.23% (95% CI: 87.2, 96.7), and a false positive rate of 12.5%. Lavage white blood cell (LWBC) count correlated poorly with the presence of significant intra-abdominal injury.

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