

A computer-based simulator for diagnostic peritoneal lavage

Alan Liu

Christoph Kaufmann

Thomas Ritchie

{aliu|ckaufmann|tritchie}@simcen.usuhs.mil

Surgical Simulation Laboratory

National Capital Area Medical Simulation Center

Uniformed Services University of the Health Sciences

4301 Jones Bridge Road, Bethesda MD 20814, USA

<http://www.simcen.usuhs.mil>

Abstract. Diagnostic peritoneal lavage (DPL) is an emergency diagnostic procedure performed when intra-abdominal bleeding secondary to trauma is suspected. This procedure is part of the surgical skills section of the Advanced Trauma Life Support course. DPL is traditionally taught using anesthetized animals or cadavers. For reasons described below, these alternatives are not ideal. We have developed a computer-based diagnostic peritoneal lavage simulator. Our system addresses the shortcomings of the traditional method. We have used our system to teach ATLS[®]. Preliminary results suggests that our system is effective.

1. Introduction

The Advanced Trauma Life Support (ATLS[®]) course trains doctors in optimal assessment and resuscitation techniques for the seriously injured patient. ATLS[®] is recommended for all doctors caring for patients with serious injury. An average of 19,000 doctors in over 30 countries are trained annually in ATLS[®] [1]. This course is taught to all fourth year medical students at our university. The ATLS[®] course includes a surgical skills component. Students are taught tube thoracostomy, surgical airway, pericardiocentesis, and diagnostic peritoneal lavage. These skills are taught using cadavers or anesthetized animals (i.e. wet models). Groups of up to four students learn on each model.

Wet models have limitations. They are single use resources. For example, procedures requiring incisions can be performed at most once in a specific anatomic location. The same location cannot be reused for the next student. In

addition, students who have made a mistake cannot redo the incorrect step. Cadavers are expensive, and can be difficult to procure. Most require refrigerated storage, and must be thawed prior to use. They do not have the physiology of live patients. Anesthetized animals do not have the same anatomy as humans. This can be a problem when teaching ATLS[®] skills such as pericardiocentesis [2]. Animal specimens are individually inexpensive, but require separate maintenance facilities, and staff to manage their care and feeding. Both the latter items may be costly. Finally, the use of animals and cadavers for medical education may raise ethical concerns.

In a previous paper [2], we described our work in exploring alternatives to wet models. Diagnostic peritoneal lavage (DPL) was not discussed. In this paper, we extend our work by describing a computer-based simulator for teaching DPL in ATLS[®]. A brief description of the procedure is given below. Section 2 describes our system in more detail. Section 3 describes our preliminary findings. Section 4 discusses the implications of our work. Finally, section 5 summarizes the key points of our paper.

DPL is performed when intra-abdominal bleeding secondary to trauma is suspected. The procedure is performed when alternative diagnostic methods such as computerized tomography (CT) or ultrasound imaging are unavailable, or when the patient's condition does not allow them to be performed. The DPL procedure involves several steps. First, the appropriate site is selected and a small incision made after local anesthesia. The incision minimizes drag on the catheter at a later step. A cannula is inserted in the incision and is used to penetrate the midline fascia in the abdominal wall. During insertion, the surgeon feels a sudden give or "pop" as the cannula passes through the fascia. Care must be taken not to insert the cannula too deeply and perforate the bowel. A flexible guidewire is passed through the cannula. The cannula is then removed and a catheter threaded over the guidewire. The guidewire is then removed. As a preliminary test, a syringe fitted on the catheter is used for aspiration. If gross blood is detected, bleeding is confirmed. If no blood is aspirated, the syringe is removed. Saline solution is introduced into the abdominal cavity through the catheter. The solution is then drained and sent for laboratory analysis.

DPL is normally taught on anesthetized animals. In the following section, we present a computer-based system that provides an alternative for current practice.

2. Method

Our system consists of a desktop computer system and a commercially available haptic interface. The computer has 128 Mb of memory, a Pentium // 300Mhz CPU, and a Gloria Elsa Synergy graphics card. The computer uses the Windows NT operating system. OpenGL is used to access the graphics hardware. The haptic interface is the CathSim AccuTouch device manufactured by HT Medical Systems. Fig. 2 illustrates. The device contains a needle carrier. The needle carrier has a three degree-of-freedom (DOF) orientation sensor. Pitch, yaw,



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and depth of insertion can be detected. The carrier also provides a one DOF passive haptic feedback. As the user pushes or pulls the carrier, resistance can be felt. The degree of resistance is controllable. By dynamically controlling the degree of resistance, it is possible to simulate the sensation of a needle piercing through various layers of tissue. Encoders located co-axial to the needle carrier permit guidewires, cannulas, and catheters to be detected. Our system uses the haptic interface to simulate the effect of inserting the cannula and other DPL instruments in the abdomen.

The system is initialized with a cannula in the needle carrier. When the program begins, the student is presented with a list representing the steps in the DPL procedure. Fig. 2 illustrates. Items on the list have been randomized. The student is required to know the correct sequence. The system does not proceed until the correct next step is chosen. Incorrect choices are recorded and reported at the end of the simulation. When a correct action is selected, the system displays a model of the human abdomen. The student is then prompted to perform the action. We describe each step in more detail.

Select site and make incision. The system displays an external view of the abdomen. The student uses the mouse to click on the correct location. Several regions with different degrees of desirability can be defined. For example, if the student clicks on an area normally reserved for individuals with pelvic fracture, the system reports that fact. A correct choice permits the student to proceed to the next step. Fig. 3 (top left) illustrates.

Insert cannula. The system displays an image of a cannula over the abdomen. The student controls the image with the haptic device. As the cannula is inserted, the system adjusts the resistance on the haptic device. The student feels an effect similar to passing a cannula through layers of abdominal tissue. The characteristic “pop” of the needle passing through the fascia is simulated by an abrupt decrease in resistance at the appropriate depth. During insertion, the student’s entry angle, location, and depth of insertion is compared with instructor-defined optimal

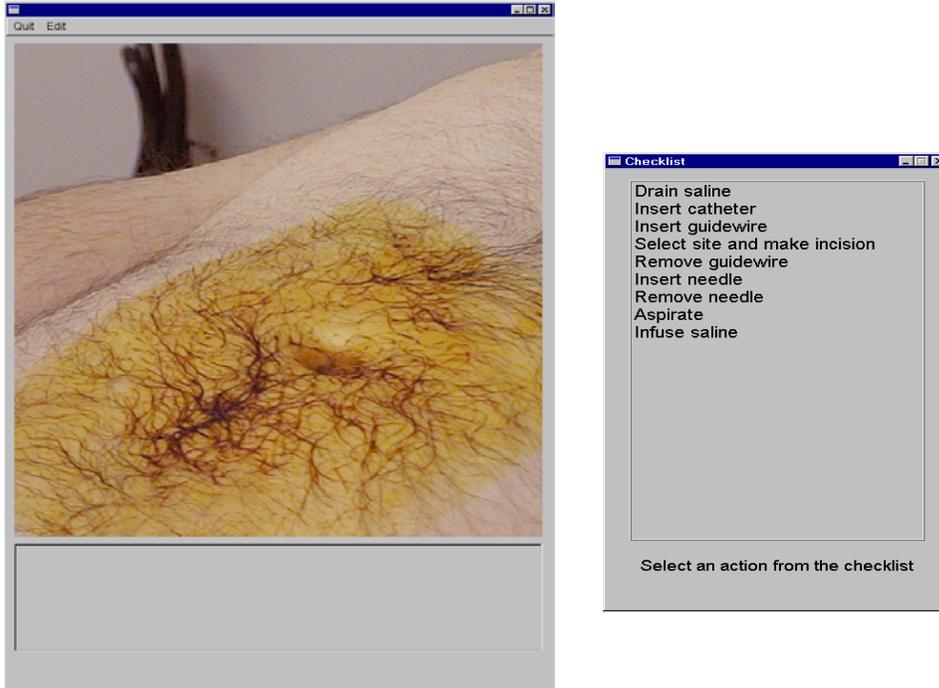


Fig. 2: Simulator user interface. The right window contains a checklist of actions. The left window permits individual actions to be performed.

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Insert guidewire. With the cannula inserted, the student inserts the guidewire. The system displays the image of a guidewire over the cannula. An encoder in the shaft of the needle carrier detects the guidewire's passage. The guidewire's image updates accordingly when this occurs. The system reports an error if the guidewire has been inserted too deeply, or not deeply enough. Fig. 3 (middle left) illustrates.

Remove cannula. An important precaution during DPL is not to lose direct control of the guidewire. As the cannula is being removed, its position relative to the guidewire is monitored. If the guidewire slips into the cannula, an error is reported by the system.

Insert catheter and remove guidewire. An image of the catheter is displayed. The student inserts the catheter over the guidewire and into the needle carrier. The system tracks the catheter's movement and updates the image accordingly. As with the previous step, loss of control over the guidewire generates an error message. Fig. 3 (middle right) illustrates.

Aspirate. An image of a syringe attached to the catheter is displayed. The user starts aspiration by clicking on a button on the screen. Depending on the system configuration, this step may draw either gross blood, or no blood is extracted. The student is prompted for the correct action based on the image shown. By default, the system randomly displays gross blood half the time. The instructor can override and force a positive or negative outcome as desired. If gross blood and the correct student response is obtained, the system bypasses the remainder of the

simulation and generates a report of the student's performance. Fig. 3 (bottom left) illustrates.

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Report generation. The simulator concludes by generating a summary of the student's performance. Each step corresponds to one section of the report. In each section, errors encountered for that step are reported.

3. Preliminary results

Permission was obtained to investigate teaching an ATLS® course using alternatives to wet models. DPL was taught using the computer-based system described in this paper. The course was attended by a group of six surgery residents and three staff surgeons, each of whom had previously taken the ATLS® course. A survey was conducted after the course. Students were asked to rate individual components of the course on a scale of 0 (poor) to 3 (very good). Of the nine students, seven rated the DPL component as 3 (very good), and two rated it as 2 (good). The average was 2.8. This compared favorably with the other components in the surgical skills section.

4. Discussion

Computer-based simulators have several advantages over wet models. Simulators can incorporate anatomically correct models. They do not bear signs of previous usage and can be deployed repeatedly. Unlike cadavers, simulators can be programmed to provide the correct physiological response. More importantly, their responses can be altered to suit the lesson being taught. Computer-based simulators do not have significant maintenance or storage costs. They do not require laboratory or clinical facilities for deployment.

Simulators have some disadvantages. The initial cost may be high, making their purchase less attractive. However, the availability of powerful personal computers at decreasing prices may ameliorate this. For example, the hardware cost of our DPL simulator is less than \$7,000. In addition, different kinds of simulations can be run on the same hardware.

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The preliminary results presented are encouraging. They suggest that the DPL simulator is useful in teaching this skill. However, the study involves a small sample, and does not compare our system with the use of wet models. The study also did not determine the specific contribution of our simulator to the overall success of the DPL session. Additional, more detailed studies are being planned.

5. Conclusion

We described a computer-based system for teaching DPL. Our system has several advantages over wet models. They include: reusability, having the correct anatomy and physiology, and low operating cost. We have used our simulator as part of an ATLS® course. A postcourse survey suggests that the DPL simulator may have value in teaching this surgical skill.

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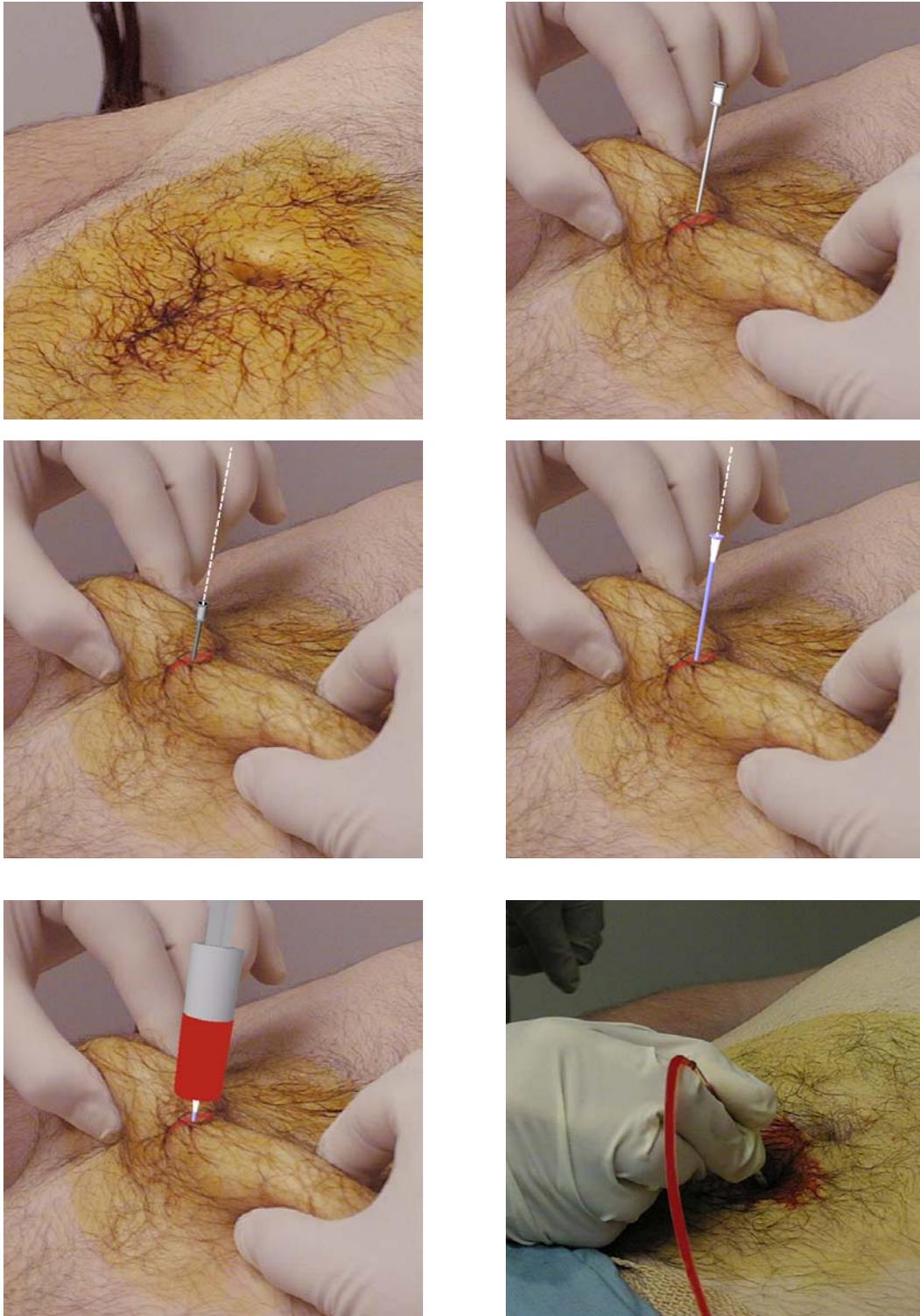


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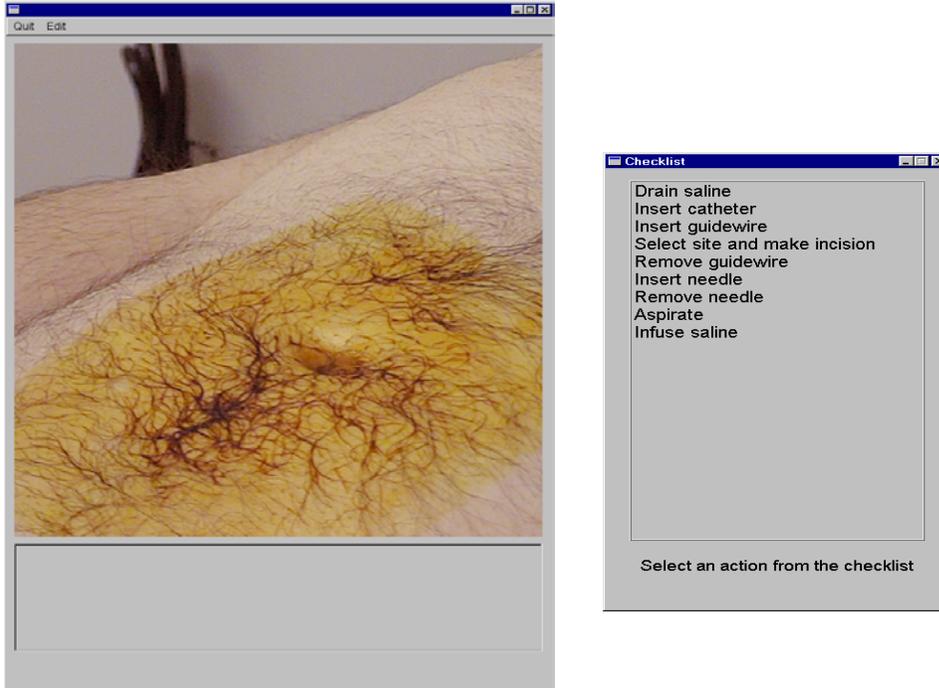


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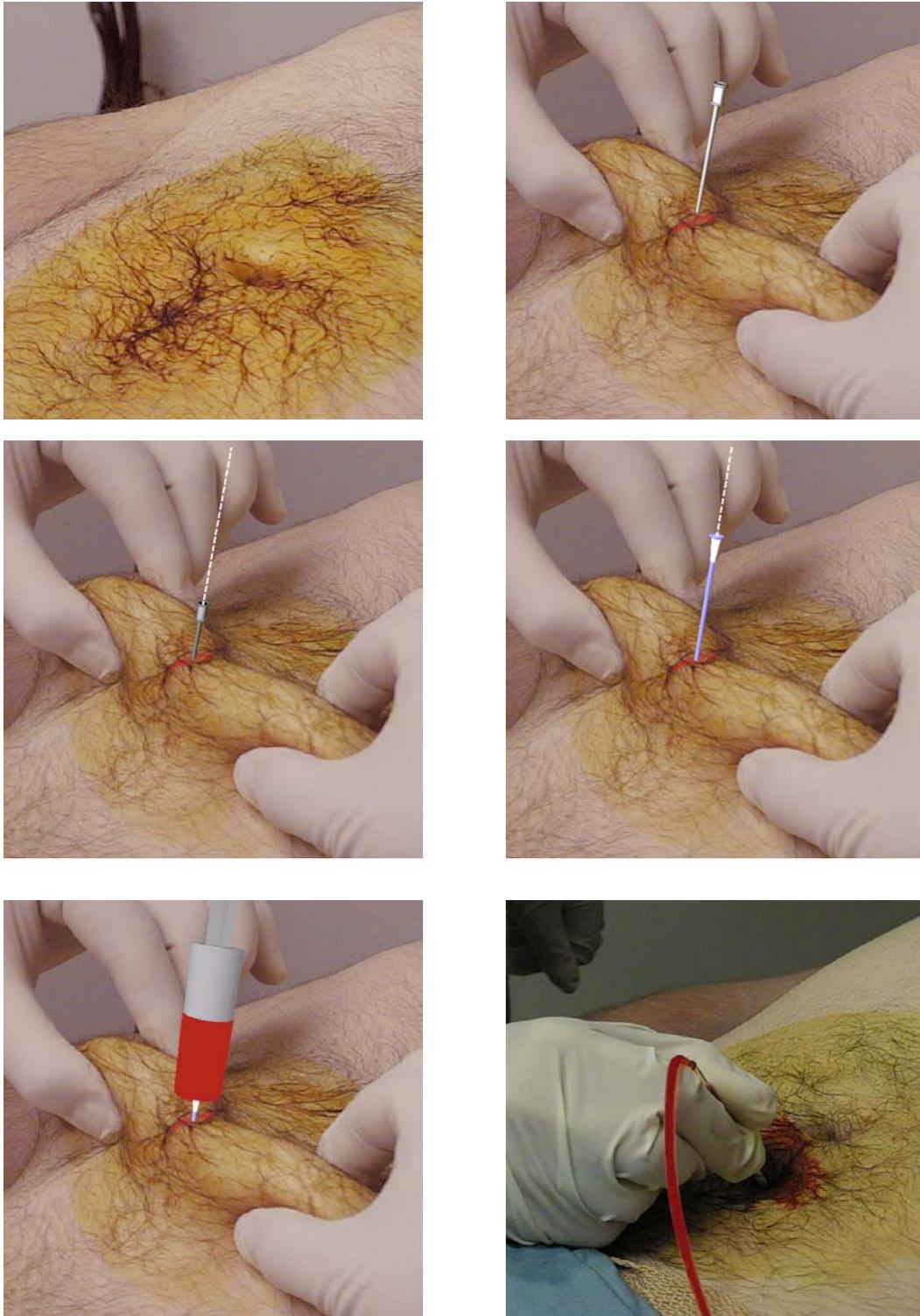


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