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Technical Report

Design and Feasibility of PASSIST, a Passive Instrument Positioner

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ABSTRACT

***Background and Purpose*: During minimally invasive procedures, an assistant controls the camera and often a laparoscopic grasper. Ideally, the surgeon should be able to manipulate the instruments because the indirect way of control complicates the surgeon's observation and actions and disturbs eye-hand coordination. Reported replacements for the assistant are active positioners, "robots," such as the Aesop™ and the EndoAssist™. Because positioning instruments is often a static task, the Academic Medical Center has developed a passive assistant for instrument positioning (PASSIST) to allow solo surgery.**

***Methods*: The PASSIST was designed to be simple, fully autoclavable, slender, and stiff. The joints have adjustable friction and spring compensation for stabilizing the instrument in a fixed position, enabling intuitive single-hand repositioning.**

***Results*: The PASSIST has been tested in three laparoscopic procedures: cholecystectomy, laparoscopically assisted vaginal hysterectomy, and spondylodesis. In all of these procedures, the assistant could be replaced satisfactorily, and the surgeon was able to manipulate all of the instruments on his own.**

***Conclusion*: Solo surgery using the PASSIST is feasible. The positioner enables the surgeon to manipulate the viewpoint, to have a stable image, and therefore to improve observation and manipulating actions.**

INTRODUCTION

LAPAROSCOPIC SURGERY is being applied increasingly as an alternative to conventional surgery. Laparoscopy was initially developed as a diagnostic procedure,[1–3] but nowadays, the technique is widely used to perform operations. Laparoscopic procedures such as cholecystectomy have become established with respect to the technique, the tools, and the assignment of tasks to the members of the operating team (Fig. 1).[2,4]

The laparoscopic alternatives have the advantages of reduced trauma for the patient and a shorter hospital stay. However, they present a much more complicated technique for the surgeon.[4–7] Direct contact is lost because of the interposition of instruments between the tissue and the surgeon's hands.6,8,9 Moreover, direct three-dimensional vision of the operation field is also lost. This loss is only partly compensated for by the laparoscopic camera.

In addition, the camera is controlled most of the time

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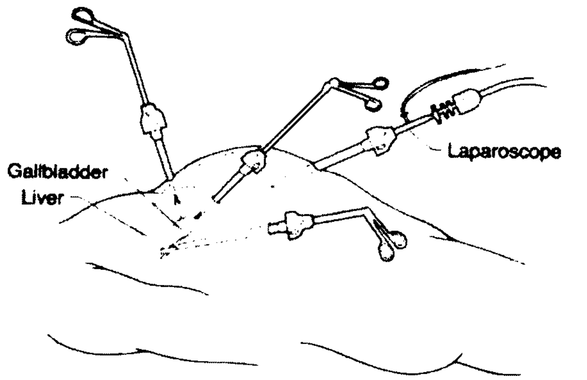

FIG. 1. Diagram of the abdomen and the instruments for cholecystectomy.

by an assistant instead of the surgeon (Fig. 2). This indirect way of controlling the camera complicates the surgeon's observation and manipulation actions and disturbs the surgeon's eye-hand coordination.[4,10] It can lead to communication problems between the surgeon and the assistant and to an unsteady image and inaccurate viewpoint when the assistant has to maintain a fixed position for a long time.

The negative effects of the indirect positioning of the camera can be reduced by replacing the assistant by a camera positioner. Dissection is easier if the camera is supported by a positioner instead of an assistant, because positioners do not make unexpected or conflicting image movements, they do not get tired, and they therefore provide a stable image.[12,13] For example, in laparoscopic cholecystectomy (LC), this stability could be advantageous in the dissection phase in which an accurate central image is very important. Moreover, a second positioner could be used in LCs to lock the laparoscopic grasper that is used to stretch and present the gallbladder. In this way, the surgeon would be able to perform the operation without an assistant, controlling the camera position personally and locking the camera in the desired position, resulting in a steady image and facilitating dissecting actions. Commercially available remote or voice-controlled active positioners (robots), such as the Aesop™ (Fig. 3) and the EndoAssist™, indeed provide a stable image and cannot get tired. In addition to the stabilizing task, the active positioners can be controlled by the surgeon without interrupting manipulation actions. However, although they function properly, these robots are relatively slow because of the time delay. They also need a lot of space, are expensive, cannot be sterilized, and control only the camera.

Passive positioners are also available, such as the Leonard Arm™, The Tiska™, and the MICTECFIX™ (Fig. 4). Most of these positioners are mechanical arms with a series of linkages and instrument clips. Generally, two hands are needed to reposition the instrument or the endoscope, or footswitches are needed to release electromagnetic or pneumatic brakes, which makes them relatively large and cumbersome to handle.

The aim of this study was to design, build, and evaluate an easy-to-handle, slender but stiff, passive laparoscopic positioner that would allow the surgeon to perform laparoscopic procedures without an assistant.

DEVELOPMENT OF INSTRUMENT POSITIONERS

The Department of Medical Technological Development (MTO) is an engineering department within the AMC Hospital, including a workshop for prototyping. This situation gives us the opportunity to develop medical instruments in close collaboration with medical re-

FIG. 2. Assistant (right) holding camera and laparoscopic grasper.

FIG. 3. Aesop robotic arm (Computer Motion Inc.).

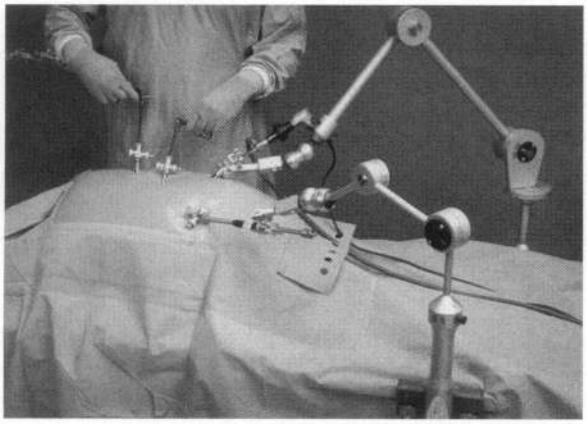

FIG. 4. Leonard Arm, a passive positioner (Leonard Medical Inc.).

searchers. An experimental surgery department and the operating theater of the Academic Center enable us to test and evaluate instruments in the same building where the devices are designed and built. The passive instrument positioner described was designed in close collaboration with the surgical department of the AMC.

Multidisciplinary meetings resulted in the following design criteria:

- Slender mechanism, not interfering with the actions of the surgical team;
- Easy to connect to the table rail and easy fixation of the laparoscopic instrument;
- Completely sterilizable;
- Intuitive and easy repositioning of the instrument with one hand;
- Repositioning of the instrument without exerting tension on or causing damage to the abdominal wall at the incision point.

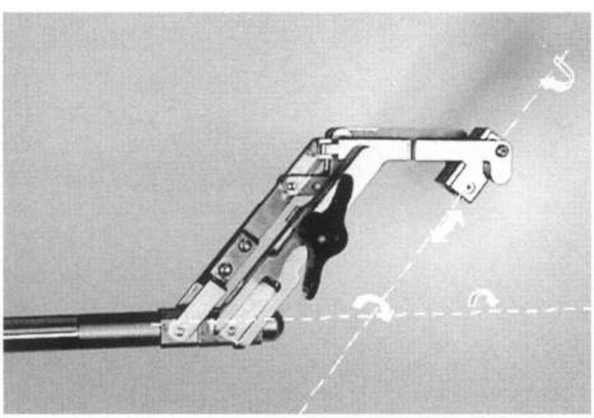

FIG. 5. Parallelogram mechanism with remote center of motion (intersection of dashed lines).

In laparoscopy, the camera and instruments have four degrees of freedom, three rotations around the incision point, as well as one translation through the incision point. The positioner we developed is a parallelogram mechanism that allows only movements in the four degrees of freedom that are possible in laparoscopy (Fig. 5). This stiff but slender mechanism has a stationary center of motion. Because this center is at the incision point in the abdominal wall, all reaction forces are absorbed by the mechanism. This results in minimal skin tension near the incision.

By manually adjusting just one knob, the friction in all the joints can be varied, which gives the mechanism a variable resistance to movement, just enough to stabilize the instrument in a fixed position. To reposition it, the surgeon gently moves the positioner or the instrument with one hand. When released, the instrument remains in the new position. One axis of rotation is spring loaded to compensate for the weight of the endoscope, including the videocamera and wires. This construction creates low friction in that joint, so repositioning of the endoscope is simple.

The device, including the rail clamp and connection bar, is stainless steel with an open structure and no electrical components and can be sterilized. The positioner can be connected to the rail over the drapes at any location (Fig. 6). The slender bar between the mechanism and the rail interferes little with the other instruments.

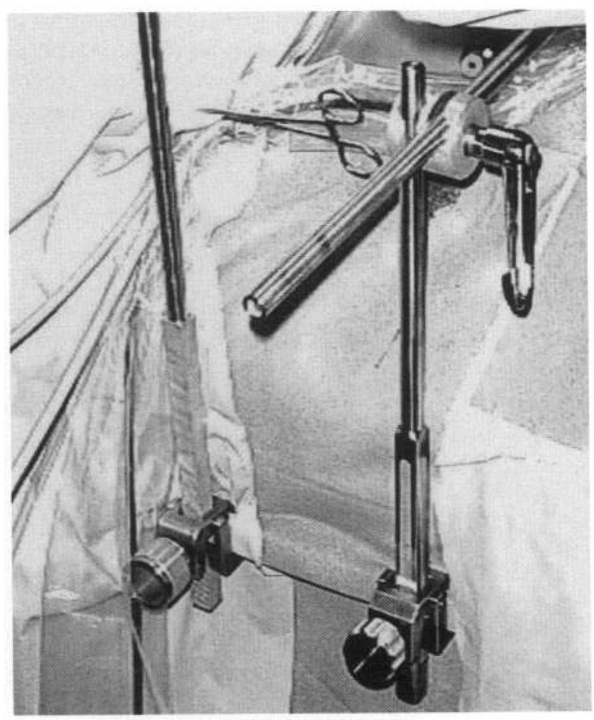

FIG. 6. Rail clamp and connection bar.

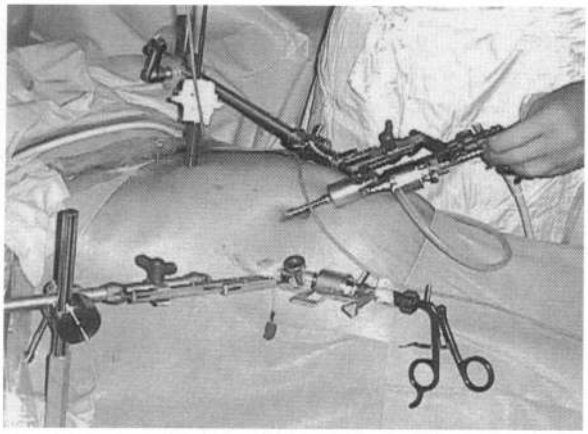

FIG. 7. LC with two passive positioners, one holding camera and one holding laparoscopic retractor.

CLINICAL RESULTS

The advantages and drawbacks of surgical procedures and new instruments are frequently analyzed by evaluation of the complications in the postoperative period or by comparing total operating times in phantom or animal experiments.[6,14,15] However, these evaluations do not provide any insight into the specific efficiency, functionality, or limiting factors of the instrumentation used during the operation. Therefore, analysis and critical evaluation of the technical equipment in a clinical setting is of great importance for minimally invasive procedures.[11]

After we tested our device successfully in a phantom experiment, we tested it in a few procedures, namely LC, laparoscopically assisted vaginal hysterectomy, and laparoscopic spondylodesis in three hospitals with three surgeons.

In standard LC, the assistant has to stabilize the laparoscope and a grasper during the dissection. In the experimental LC, the new passive positioners are used to take over the stabilization of the camera and the grasper from the assistant (Fig. 7).

In a standard laparoscopically assisted vaginal hysterectomy or laparoscopic spondylodesis (Fig. 8), the assistant simply stabilizes the laparoscope, so in the experimental setting, only one passive positioner was applied, to take over the stabilization of the camera from the assistant.

In all these procedures, the surgeon could perform the operation without an assistant. All surgeons indicated that the Passive Positioners are indeed small and slender and did not interfere with the surgical actions. The whole system is easy to use and can be fully sterilized even in a small autoclave. Single-handed repositioning of the laparoscope is possible in any position when the mechanism is spring loaded to compensate for gravitational forces (Fig. 9). In the laparoscopic spondylodesis, the PASSIST was an advantage because during that procedure, an X-ray C-arm was needed, and there was simply no room for the assistant near the table.

Sometimes when the surgeon needed an extra hand, the scrub nurse could assist; e.g., by repositioning the laparoscope. The surgeons had the impression that with the endoscope positioner, the image was much more stable than with an assistant. Releasing an instrument in order to reposition the endoscope or the retractor was not found to be an important disadvantage.

DISCUSSION

The slender laparoscopic positioner designed and built by the Medical Technological Development Department of the AMC makes it possible for a surgeon to perform solo surgery if one or two positioners are applied. The clinical trials indicate that the positioners did their job well and provide us with data to improve our device.

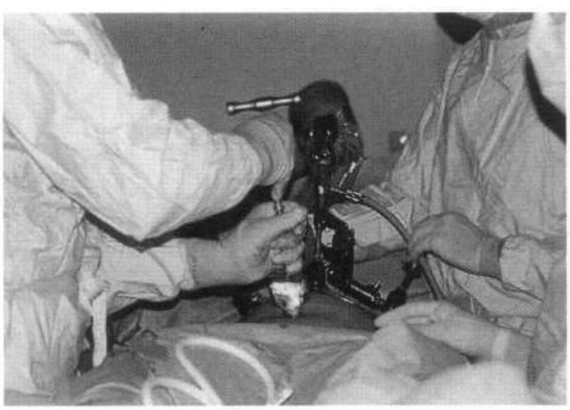

FIG. 8. Laparoscopic spondylodesis with one positioner to stabilize laparoscope.

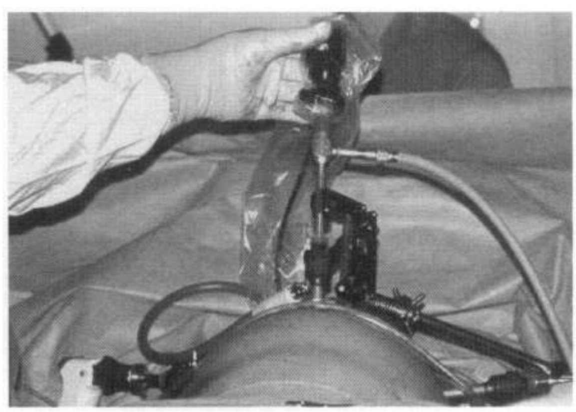

FIG. 9. Easy repositioning by using compensation spring and adjustable friction.

We tested the PASSIST in three different procedures, and we have the impression that this device is useful in all laparoscopic procedures except those where frequent camera movements are required.

To compare a standard procedure with an operation with the PASSIST, we recently began a randomized clinical study to evaluate these positioners. The procedure selected for investigation is the LC because it is the most frequently performed laparoscopic procedure and is carried out in accordance with a standard protocol. This study will evaluate the advantages and limitations of the new instrument positioners in terms of reduction of action and time in the amount of assistance and the stablility of the image of the operating area.

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