

Ergonomics: Requirements for Adjusting the Height of Laparoscopic Operating Tables

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ABSTRACT

Background and Objectives: In the last few years many new instruments and devices have been developed and introduced into the operating room (OR). A debate has been ongoing about the optimal ergonomic posture for the operating staff. From practical experience, we have learned that the operating tables cannot be adjusted adequately to allow surgeons of different stature to maintain a comfortable posture. The goal of this study was to establish the most ergonomic table height for the particular physique of the surgeon and the different types of laparoscopic instrument handles that he or she uses.

Methods: In a simulated model, two probands of different stature (50th {BS 50} and 95th {BS 95} percentile) used laparoscopic instruments with four different handle designs (shank, pistol, axial, and rod). The instruments were inserted into a board in three different angles (IA) = 20°, 30°, 40°. Additionally the elbow angles (EA) of the volunteers were fixed to either 90° or 120°. For every variable (size of surgeon and his or her elbow angle, design of handle, insertion angle of the instrument) the height of the board, as a parameter for the level of the abdominal wall of a patient with pneumoperitoneum, was measured from the floor.

Results: All parameters had an effect on the optimal operating table height. The lowest required operating table level was 30 cm, the highest was 60.5 cm. In laparoscopic surgery—long shafted instruments and

patients with pneumoperitoneum—the tabletops are too high for over 95% of all surgeons.

As skin incision and wound suture are performed the conventional way, the operating tabletop must be adjustable up to the common height of 122 cm.

The maximal difference between the optimal heights of the OR-table for one volunteer using two different handles with different insertion angles of the instruments (BS 95, EA 90°, IA 20°, rod handle to BS 50, EA 120°, IA 40°, axial handle) was about 27 cm.

Conclusion: New operating tables with a much lower adjustability are necessary to fulfill ergonomic requirements. The use of differently designed handles can hinder the ergonomic posture of the surgeon, because each handle requires a different working height.

Key Words: Operating room table, Laparoscopy, Ergonomics, Human factors, Surgery.

INTRODUCTION

In the last 10 years, laparoscopy has become part of visceral surgery, and many new instruments and devices have been developed. These instruments meet the requirements of entry into the abdominal cavity through a trocar, but they do not comply with the anatomic and physiologic needs of the surgeon. The ergonomic deficiencies of the laparoscopic working place have been described in detail in many publications.¹⁻⁸ The Society of American Gastrointestinal Endoscopic Surgeons (SAGES) recognized the importance and established a study group to improve ergonomics in the operating room.⁹⁻¹¹

This paper addresses the problem of adjusting the operating (OR) table to the optimal ergonomic height.

Almost a hundred years ago, the adjustability of the operating table for open surgery had already been discussed. De Quervain pointed out the importance of adjustability of the table for the positioning of the patient in relation to the surgeon.^{12,13}

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The adjustability of current operating tables ranging between 73 cm and 122 cm¹⁴ is sufficient for open surgery. Only rarely does a surgeon wish to position the table above or below this height in traditional surgery.

In laparoscopic surgery, though, the situation is radically different. Often the table cannot be lowered sufficiently for precise and relaxed work. Surgeons compensate for this by elevating their arms, which can be very fatiguing,¹⁵ or by climbing on a step. The small area available for surgeons' feet on a step limit their movements as well as their access to foot switches needed for high frequency (HF) surgery and eventually also for the suction and irrigation device. These devices also have to be placed on this step, and quite often these foot switches fall off⁴ (**Figure 1**).

The purpose of our study was to measure the required range of height adjustability for operating tables used in laparoscopy in relation to the stature of the surgeon, the type of handle used, and the insertion angle of the instrument.

MATERIALS AND METHODS

A perspex board simulated the abdominal wall of the patient lying on the top of the operating table. It was



Figure 1. During surgery a small surgeon is standing on a step. The foot switch for the high frequency current is likely to drop off due to limited space on the step.

fixed horizontally to conventional adjustable tripods. Various working angles for the laparoscopic instruments were simulated by holes drilled into the board at an angle of 20°, 30°, and 40°. To guide the instruments, an appropriate trocar was placed into the holes.

Four laparoscopic instruments with different handle types were fixed to the trocar. The distance between the perspex board and the transition of the instrument's handle and its shaft was kept at 25 cm. By doing so, an insertion of one third of the shaft into the abdomen was simulated, a situation that is common during surgery.

The following instruments and handles (**Figure 2**) were tested:

1. Shank handle (25.00, Wilo, Bühlertann): A very big handle, angled about 90° to the shaft of the instrument. With this arrangement the shaft is positioned above the longitudinal axis of the forearm.
2. The pistol handle (30534, Karl Storz, Tuttlingen):¹⁶ The handle is angled 75° to the shaft, which is positioned as a direct extension of the longitudinal axis of the forearm.
3. Axial handle (PM 953R, Aesculap, Tuttlingen):¹⁷ The handle is positioned in the extension of the instrument's axis. For manipulation, it is held in such a way that the shaft is positioned below the forearm axis.
4. Rod handle for HF hooks (model, KST 10,002, Karl Storz, Tuttlingen):¹⁸ As with the axial handle, the rod handle is positioned as a direct extension of the shaft. It is held in a manner similar to that used to hold a pencil; therefore, the shaft of the instrument is positioned at an angle of 90° to the forearm.

To evaluate the optimal operating table height in relation to the surgeon's height, the following experiment was performed by a tall (188 cm-95th percentile) and a smaller proband (172 cm-50th percentile).¹⁹ Therefore, the stature of approximately 50% of surgeons worldwide is represented.

The probands were standing upright next to the tripod. They were required to assume an "ergonomic basic body posture" as described in previous publications.^{4,5} With this posture, the elbow angle is between 90° to 120°. In this position, it is possible to work for a long period of time without getting fatigued. The elbow of the right arm was fixed with two plaster splints at angles of 90° and

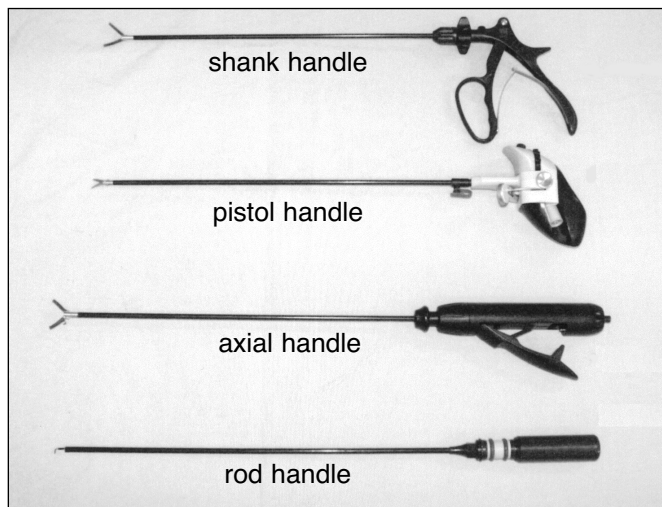


Figure 2. The four laparoscopic handles of different designs used in the test: Shank handle (25.00, Wilo, Bühlertann, Germany), Pistol handle (30534, Karl Storz, Tuttlingen, Germany), Axial handle (PM 953R, Aesculap, Tuttlingen, Germany), and Rod handle (model, KST 10,002, Karl Storz, Tuttlingen, Germany).

120°. The alignment of the instrument, the trocar, and the perspex board was adjusted in height to the tripod in a way that the right hand could grasp the handle as comfortably as possible (**Figure 3**).

The adjusted height at the top of the perspex board was measured with a common foot rule. This value corresponds to the height of the abdominal wall of a patient with an intraoperative pneumoperitoneum.

RESULTS

The height of the operating table varies in relation to the surgeon's stature, the angle of the elbow joint, the type of handle, and the working angle of the instrument in the abdominal wall of the patient (**Table 1**).

The various handle types for laparoscopic instruments require different table heights for ergonomic manipulation when used at the same insertion angle. The axial handle always requires the lowest adjustment of the OR-table, followed by the rod or shank handle. This difference varies between 4.5 cm (IA=20°, EA=90°, small volunteer) and 14 cm (IA=40°, EA=90°, tall volunteer).

The lowest working height was required for the axial handle, which is held from above. For the small test per-

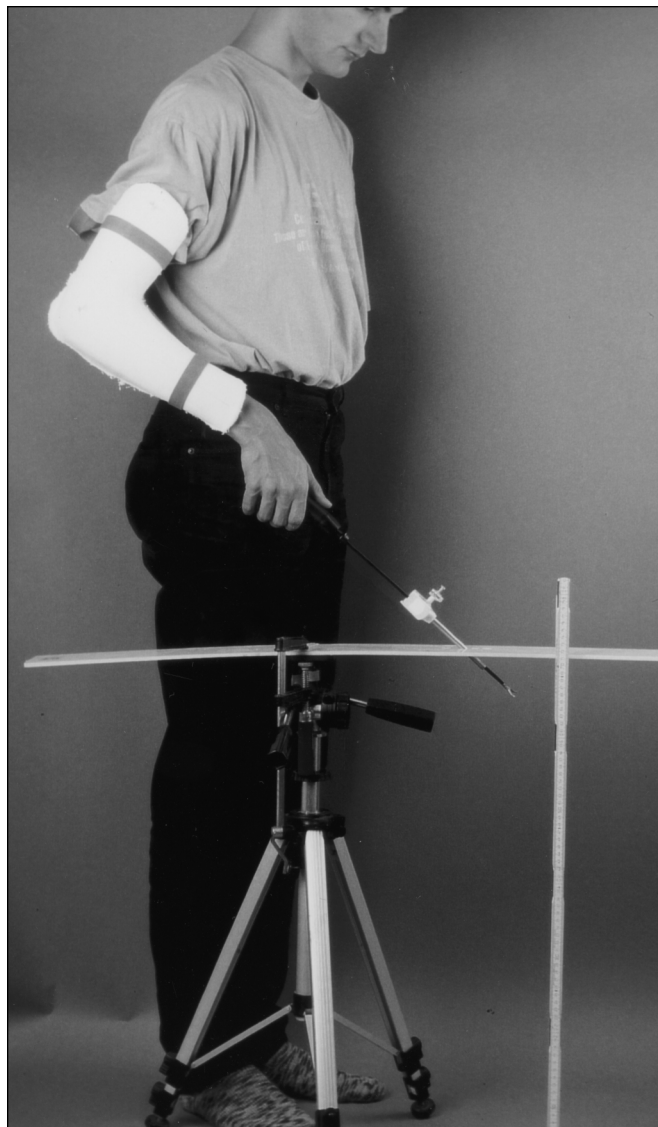


Figure 3. Experimental setup.

son who had to work with the elbow angled at 120°, the abdominal wall of the patient had to be 70 cm high, corresponding to the height of the proband's upper thigh. The tall proband needed an elbow angle of 90° when working with a shank handle and a board height of 103.5 cm, which is about 10 cm below the umbilicus (114 cm) of the proband. Therefore, the maximal vertical range of the laparoscopic operating table is 33.5 cm. For a patient with a sagittal abdominal diameter of 40 cm (for a pneu-

Table 1.
Height measurement (in cm) of the patient's abdominal wall in relation to body height and elbow angle of the probands as well as insertion angles and types of the instrument handles.

Elbow Angles	Handles	Insertion Angles					
		Volunteer 50 percentile			Volunteer 95 percentile		
		20°	30°	40°	20°	30°	40°
90°	Shank handle	96	91	86.5	103	100	95
	Pistol handle	94.5	90	82	101	95	91
	Axial handle	92.5	84	79.5	93.5	89.5	81
	Rod handle	97	91	87	103.5	98	94
120°	Shank handle	89.5	88	84	95.5	90	85.5
	Pistol handle	88.5	83	78	91	87	84.5
	Axial handle	78.5	74.5	70	87	82	76
	Rod handle	94.5	87	84	94.5	92	86

moperitoneum), the lowest operating table level should be about 30 cm, which corresponds to the middle of the lower leg of the smaller proband.

The highest working height (103.5 cm) was required for the tall proband manipulating the rod handle at an insertion angle of 20° and with an elbow angle of 90°. This height of the abdominal wall is approximately 10 cm below the possible range of currently available operating tables (73 cm table height + 40 cm patient diameter). Therefore, these tables are too high to allow for adequate working conditions for at least 95% of surgeons performing laparoscopic procedures.

At the beginning and the end of laparoscopic surgery, the common "open" techniques for disinfection, skin cut, trocar insertion and removal, and wound suturing have to be performed. Therefore, the table has to be positioned at the normal working height. Consequently, future laparoscopic operating tables should have a vertical range from 30 cm to 122 cm.

DISCUSSION

Berguer recently recommended¹¹ adjusting the operating table so that the height of the prone patient is at the level of the surgeon's upper thigh. The minimal vertical range of the operating table was not specified. Furthermore, the hands should be positioned at the level of the elbow with the forearm in a horizontal position. No mention was made of which handle to use. In the case of shank and pistol handles, the forearm position causes an ulna devi-

ation, similar to the insertion angle of the instrument.

The manipulation of an axial handle is awkward in this position, causing severe pain, cramps, and fatigue.¹⁵ For the rod handle, the horizontal arm position recommended by Berguer¹¹ may be adequate, as it usually results in an almost neutral wrist angle.

To determine adequate operating table heights, other elbow angles should also be considered. Bullinger recommends an elbow angle of 90°-120° for continuous work.²⁰ Contrary to the 90° angle, the 120° angle requires an operating table height that—according to the type of handle used and the height of the surgeon—should be as much as 10 cm lower. A table that can be adjusted within this range by the surgeon him- or herself seems desirable. This could be accomplished either by a foot switch¹⁴ or a voice or hand controlled switch.

Differently designed handles should not be used simultaneously at the same insertion angle, because this requires different postures at shoulder level for adequate manipulation. But sometimes, when working with instruments at different insertion angles, it may be necessary to use different types of handles to achieve an ergonomic posture.

The difference between the two extreme positions, small surgeon, axial handle, EA 120°, IA 40° vs. tall surgeon, rod handle, EA 90°, IA 20°, is 33.5 cm. The lowest level for the abdominal wall is 70 cm. Accordingly the table should be positioned at a height of 30 cm for a patient with a sagittal abdominal diameter of 40 cm. Although,

below the knee of the surgeon, even this level may be too high for some surgeons because the proband's height was at the 50th percentile. OR-tables that fit to 50% of surgeons could be a big advantage, because it is alarming that the currently available operating tables are too high for 95% of surgeons performing laparoscopic procedures.

For the lower position of the operating table, the following hygienic aspects should be considered: the distance between the operating level (abdominal wall) and the "floor" is equally reduced by the common use of a standing stool for different heights of surgeons and assistants. These stools, however, are neither convenient nor large enough to accommodate the surgeon and the paddle equipment. Furthermore, they also cause problems with regard to hygiene as it does not make a difference whether a standing stool elevates the floor or the table itself is lowered. For an ergonomic working posture, it is necessary to position the patient's abdominal wall at the height of the upper thigh as described by Berguer¹¹ and demonstrated in the present study. This interferes with the classic teaching that the surgeon's gown is only sterile above the belt; however, a literature search did not reveal any data that would support this rule. To avoid contamination via the surgeon, the gown should reach down to the ankles.

In open surgery, the patient is also often positioned very low. For example, in the reversed Trendelenburg position, the foot part of the operating table, depending on the model, may come close or even touch the floor.

Following consultation with the Institute for Hospital Hygiene and Environmental Medicine, University Hospital Freiburg, we assume that such a low positioning of the patient per se does not bear the danger of bacterial contamination provided the floor is regularly cleaned in between surgical procedures. However, as in open surgery, the drapes should not touch the floor.

Therefore, the draping system has to be modified to meet the hygienic requirements for a low table height in laparoscopy as well as to allow for extreme positions in open surgery.

In the future, the problem of inadequate adjustability of OR-tables may be solved in part by the advent of robotically assisted surgery. For now, however, robotics has technical, hygienic, and ergonomic deficiencies that should be solved over the next decades. Furthermore,

surgical procedures requiring the manual expertise of a surgeon and, therefore, an ergonomic work environment has to exist.

For laparoscopic surgery, special tabletop imposts are currently offered by different manufacturers of operating tables.¹⁴ Now the manufacturers are challenged to design new operating table posts to support the needs of surgeons and to optimize the safety and outcome for patients undergoing laparoscopic surgery.

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Acknowledgement: We would like to acknowledge the language editing of this paper by Maria Schierenberg and Dietrich Matern, MD.

Disclosure Statement: The authors have a financial interest in the following handles that were used in the test: "Pistol Handle" from Karl Storz (30534) and the "Rod Handle (KST 10,002)."