Objective: To determine the optimal angle between the handle and instrument shaft for endoscopic suturing.

Design: A rocker handle needle driver was used to investigate the 0°, 40°, and 80° handle-to-shaft angles. The standard task entailed closure of a 50-mm enterotomy in a nonliving porcine small-bowel model. Fifty enterotomies were performed with each angle in a random sequence.

Setting: Research laboratory in the Surgical Skills Unit at Ninewells Hospital.

Participants: Ten surgeons with previous experience in laparoscopic surgery.

Main Outcome Measures: The execution time (in minutes), leakage pressure (in centimeters of water), and suture error placement score (deviations of the entry and exit points <3 mm or >5 mm from the enterotomy edge or between sutures).

Results: The 40° handle-to-shaft angle had a higher mean (SD) leakage pressure of 43.8 (20.0) cm H2O compared with the 80° and 0° angles (31.1 [21.0] and 26.3 [19.0] cm H2O, respectively) (P<.001). In addition, the 40° angle had a lower mean (SD) suture error placement score of 13.6 (7.6), compared with the 80° and 0° angles (19.4 [9.4] and 21.1 [8.5], respectively) (P<.001). No significant difference was found in the execution time between the different angles (P=.20).

Conclusion: The best quality of laparoscopic bowel suturing, in terms of the accuracy of suture placement and the integrity of the suture line closure, was obtained with a 40° handle-to-shaft angle.
served difficulty in achieving optimal port location and surgeon posture using the 0° handle-to-shaft angle. To overcome this problem, a rocker handle needle driver with a universal lockable joint between the instrument’s handle and shaft has been designed and reported.9 The aim of this study was to investigate the optimal ergonomic handle-to-shaft angle for suturing.

METHODS

TASK

The standardized task consisted of suturing a 50-mm enterotomy made in the antimesenteric border of a nonliving porcine small bowel. Blue dots, 0.3 mm proximal and distal to the enterotomy, marked the start and end points. The bowel segment was mounted on a plastic grid covered with a green towel. The assembled task was stabilized with Velcro inside the trainer box. The base and sides of the box were made of wood, whereas the top was cardboard with strips of neoprene to allow maneuverability of the instruments while maintaining port position.

ERGONOMICS OF THE SETUP

A forward-viewing laparoscope was introduced into the trainer box so that the optical axis was perpendicular to the middle point of the enterotomy at a distance of 100 mm. A camera holder was used to fix the camera in position to eliminate the variability of the camera operator. Two rocker handle needle holders were introduced into the trainer box to form a manipulation angle of 60°, an elevation angle of 60°, and equal azimuth angles to provide the optimal port location for laparoscopic task performance.2 The monitor was located in front of the surgeon’s eyes and the center of the screen to provide the best direction for viewing the monitor.14 The trainer box was placed on a table of adjustable height so that each surgeon held the needle driver with the shoulder slightly abducted, the elbow at a right angle, and the instrument handle at elbow level. This table height minimizes discomfort and upper limb and shoulder muscle workload.1 The experiments were conducted in the same environment and under the same illumination conditions.

SURGEONS AND PERFORMANCE

Rocker handle needle drivers were used in the experiments to control the angle between the instrument’s handle and shaft. Coaxial alignment of the handle and shaft results in a 0° handle-to-shaft angle. By adjusting the lockable universal joint between the handle and the shaft, 40° and 80° handle-to-shaft angles were obtained (Figure). Ten surgeons of variable experience in laparoscopic surgery participated in the study. Each surgeon performed the task 5 times using each of the 0°, 40°, and 80° handle-to-shaft angles in a random sequence. Surgeons were instructed to close a 50-mm enterotomy by continuous through-and-through suturing, with suture bites 3 to 5 mm from the edge of the enterotomy and 3 to 5 mm apart. This task was commenced with an intracorporeal surgeon’s knot and terminated by another surgeon’s knot or an Aberdeen knot. The suture material was 2-0 braided polyester, 20 cm in length, mounted on a 23-mm Endoski needle (US Surgical, Norwalk, Conn).

VIDEOENDOSCOPIC EQUIPMENT

A 2-dimensional videoendoscopic system (Karl Storz, Tuttlingen, Germany) was used throughout the experiment. A forward-viewing endoscope 10 mm in diameter was connected to a single-chip camera, fiber-optic light cables 3.5 mm in diameter, and a high-resolution monitor (model PVM-1443MD; Sony, Tokyo, Japan). Halogen light sources were used only during the first 150 hours of their life span (about 250 hours), as significant deterioration of the light output occurs during the last 10% of the life span of the bulbs.

END POINTS

Evaluation of the quality of performance was carried out using the execution time, leakage pressure, and suture error placement score. This method for assessment of laparoscopic bowel suturing was used in previous ergonomic research.15 A visual analog scale was used to indicate the surgeon’s subjective comfort level.

Execution Time

Execution time was defined as the interval (in minutes) between the grasping of the needle drivers to start the task and the release of the needle drivers after completion of the terminal knot.

Leakage Pressure

The leakage pressure required to cause water leakage from the closed bowel segment was used as an indication of the integrity of the suture line. The apparatus used to measure leakage pressure consisted of a reservoir with a valve to allow water to fill the bowel. Bowels were tied to the system outflow pipe with chromic catgut. The height of the water column in the reservoir that caused leakage of water through the suture line or needle holes indicated the leakage pressure (in centimeters of water).

Suture Error Placement Score

The suture error placement score was used as a measure of the accuracy of suture placement. Any deviations of suture placements less than 3 mm or greater than 5 mm from the edge of the enterotomy or apart from each other were summed to produce the suture error placement score, with a lower score (in millimeters) indicating better suture placement.

Subjective Comfort Level

A subjective comfort level rating by the surgeons after each closure was obtained. The subjective comfort level was rated on a scale of 0 to 5 after the procedure, with 0 being the worst and 5 being the best.

STATISTICAL ANALYSIS

Data were normally distributed. The analysis was performed using a 2-way analysis of variance with replication. The sig-
The 40° handle-to-shaft angle resulted in suture line closures that had the highest leakage pressure and the lowest suture error placement score (Table). The leakage pressure and suture error placement score were significantly better with the 40° compared with the 0° and 80° angles (P < .001), with no significant difference between the 0° and 80° angles (P > .20).

The mean (SD) visual analog score was 4.2 (0.8), 3.2 (0.6), and 1.1 (1.7) for the 40°, 80°, and 0° angles, respectively. Surgeons were more comfortable using the 40° and 80° handle-to-shaft angles compared with the 0° angle (P < .005), but there was no significant difference in the subjective comfort level between the 40° and 80° angles (P = .20).

The present study confirms that the traditional fixed 0° handle-to-shaft angle is not the optimal configuration for laparoscopic bowel suturing. The 40° handle-to-shaft angle was associated with the best performance as shown by objective evaluation (lowest suture error placement score and highest leakage pressure) and subjective comfort level by the surgeons. This may be explained by the optimal location of the upper limb joints during bowel suturing using the 40° handle-to-shaft angle. Although the control of table height allowed consistent positioning of the upper limb joints at the start of the experiments with different handle-to-shaft angles, joint movements were noted to vary during bowel suturing. The 40° and 80° angles maintained the ideal shoulder and elbow positions, with the shoulder slightly abducted and the elbow flexed at 90° to 120°, whereas the 0° handle-to-shaft angle was associated with greater abduction at the shoulder and acute flexion of the elbow. Extreme abduction at the shoulder has been associated with increased workload and fatigue of the deltoid muscle. In addition, the 40° handle-to-shaft angle was noted to maintain the natural position of the wrist at 25° to 35° dorsiflexion. The 0° handle-to-shaft angle was associated with ulnar deviation of the wrist, whereas the 80° angle was accompanied by radial deviation. This results in a reduction in the strength of the handgrip by 15% with ulnar deviation and by 18% with radial deviation. Furthermore, Matern and Waller reported that the 0° handle-to-shaft angle requires ulnar deviation of 20° to 30° and greater shoulder involvement to direct the shaft diagonally downward toward the patient. The in-line handle-to-instrument shaft to instrument requires a higher muscle workload compared with the angled handle-to-shaft instrument design. Nevertheless, our explanation of joint movements with different handle-to-shaft angles needs further ergonomic and time-motion studies to obtain objective data that quantify joint movements.

**COMMENT**

The study has implications in clinical practice and instrument design. The 40° handle-to-shaft angle should improve the quality of laparoscopic task performance in the operating room. It is likely, however, that there are individual preferences reflecting anatomical differences; for this reason, laparoscopic instruments with lockable universal joints enabling adjustment of the handle-to-shaft angle provide the best solution. In practice, the position of the wrist joint depends on the angle between the instrument’s handle and shaft, the way of holding the handle, and the height of the operating table. The hand and forearm longitudinal axes should be nearly aligned as possible. The ergonomic principle is to bend the tool, not the wrist. Nevertheless, if a fixed handle-to-shaft angle is adopted, this needs to be about 40°, and the traditional handle design in line with the shaft (0° angle) should be avoided.

We acknowledge that the ideal ergonomic position of the surgeon described in this study may be difficult to achieve in the operating room, especially when the surgeon operates from the side of the operating table with the arm stretched over the patient, often in extreme abduction. In addition, the level of the patient on the operating table may be too high for the surgeon because of build and abdominal distension by the capnoperitoneum. In hand-assisted laparoscopic surgery, the surgeon adopts a lordotic stance as he or she operates with one hand inside the patient, with the external hand holding standard laparoscopic instruments. In both of these clinical circumstances, the ability to adjust the handle-to-shaft angle with the rocker handle represents a considerable advantage and enables the surgeon to acquire a more comfortable position, but the handle-to-shaft angle may be different from that reported in the study.

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**REFERENCES**

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