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ABDOMINAL IMAGING
ORIGINAL ARTICLE

"Surface map" of the appendix: a novel tool for the preoperative demonstration of appendicular location with reference to McBurney's point using a multidetector CT

Nitin P. Ghonge, Vivek Setia, Bharat Aggarwal

PURPOSE
In this study, we evaluated the role and relevance of multidetector computed tomography (MDCT) "surface map" of the appendix in demonstrating the variations in the location of the appendicular base with reference to McBurney's point and its likely clinical implications during an open appendicectomy.

MATERIALS AND METHODS
This prospective study included a total of 74 patients who underwent an MDCT study of the abdomen for various clinical indications. Post-processing of the data was performed and a "surface map" of the appendicular base was reconstructed with a superimposed measurement grid. The variation in the appendicular base location with reference to McBurney's point was analyzed along the cranio-caudal and medio-lateral axes.

RESULTS
The maximum deviation in the location of the appendicular base was +10.0 cm along the cranio-caudal axis and -4.2 cm along the medio-lateral axis. The average cranio-caudal deviation was +2.79 cm, while the average medio-lateral deviation was +0.146 cm. In the subgroup of 16 patients who had appendicular inflammation, the maximum deviation was +8.8 cm along the cranio-caudal axis and +3.0 cm along the medio-lateral axis. The average cranio-caudal deviation in this subgroup of patients was +2.77 cm; the average medio-lateral deviation was +0.77 cm.

CONCLUSION
The MDCT "surface map" of the appendix is an effective tool that can convey precise information regarding appendix location to the operating surgeon. There are significant variations in the location of the appendicular base with reference to McBurney's point. These variations are more pronounced along the cranio-caudal axis than the medio-lateral axis. Accurate preoperative localization of the appendicular base with MDCT will help surgeons optimize the initial incision for an open appendicectomy, thus, minimize extension-related incision risks.

Key words: • *appendix* • *multidetector computed tomography* • *appendicitis*

From the Division of Body Imaging (N.P.G. ✉ *drnitinpghonge@gmail.com*), Diwanchand Imaging Research Center, New Delhi, India.

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According to conventional teaching in surgical practice, McBurney's point is the anatomical landmark for locating the appendix and is commonly described as the junction of the lateral and middle thirds of the line joining the right anterior superior iliac spine and the umbilicus (1). Several studies have, however, suggested a significant discrepancy between the McBurney's point and the exact anatomical location of the appendix (2, 3). Multidetector computed tomography (MDCT) is a "one-stop" imaging solution for effective diagnosis of acute appendicitis, with a sensitivity and specificity ranging from 87%–100% and 89%–99%, respectively (4). Similar to the way surgeons use McBurney's point to decide the site of an open appendicectomy incision, the MDCT "surface map" provides a representation of the appendicular base over the anterior abdominal wall in a single image.

The present study evaluated the role of MDCT "surface mapping" of the appendix in demonstrating the variation in the location of the appendicular base with reference to McBurney's point and also to anticipate the surgical implications of these results in patients with acute appendicitis.

Materials and methods

This prospective study included a total of 74 patients who had MDCT (Somatom Sensation Cardiac 64 CT scanner, Siemens AG Healthcare, Erlangen, Germany) of the abdomen for varied clinical indications over a period of two months. Patients with a clinical history of any abdominal surgery, systemic malignancy, radiotherapy, or tuberculosis were excluded. A contrast-enhanced CT study of the abdomen was performed in venous phase with a data acquisition time of 6.15 s, scan delay of 60 s, beam collimation of 0.6 mm, gantry rotation time of 0.5 s, and pitch of 1.15. The peak tube voltage range was 100–120 kV, and the current range was 180–225 mAs, using the "care-dose" technique. The images were reconstructed at 3 mm thicknesses in the axial, sagittal, and coronal planes. Because the study did not affect the routine filming and reporting pattern, no ethical approval was required. Post-processing of the MDCT data was performed using the INSPACE software (Siemens AG Healthcare) and a "surface map" was reconstructed with a superimposed measurement grid. The software utilized the volume rendering technique (VRT) of MDCT. A detailed step-wise algorithm with explanatory images is shown in Fig. 1. An illustrative MDCT "surface map" is shown in Fig. 2. The "zero" of the measurement grid corresponded to the umbilicus on the "surface map" image. Post-processing was performed by a single CT technologist, under the direct supervision of the radiologist. The variations in the location of the appendicular base with reference to McBurney's point were tabulated along the cranio-caudal and medio-lateral axes. The location of the appendicular base along

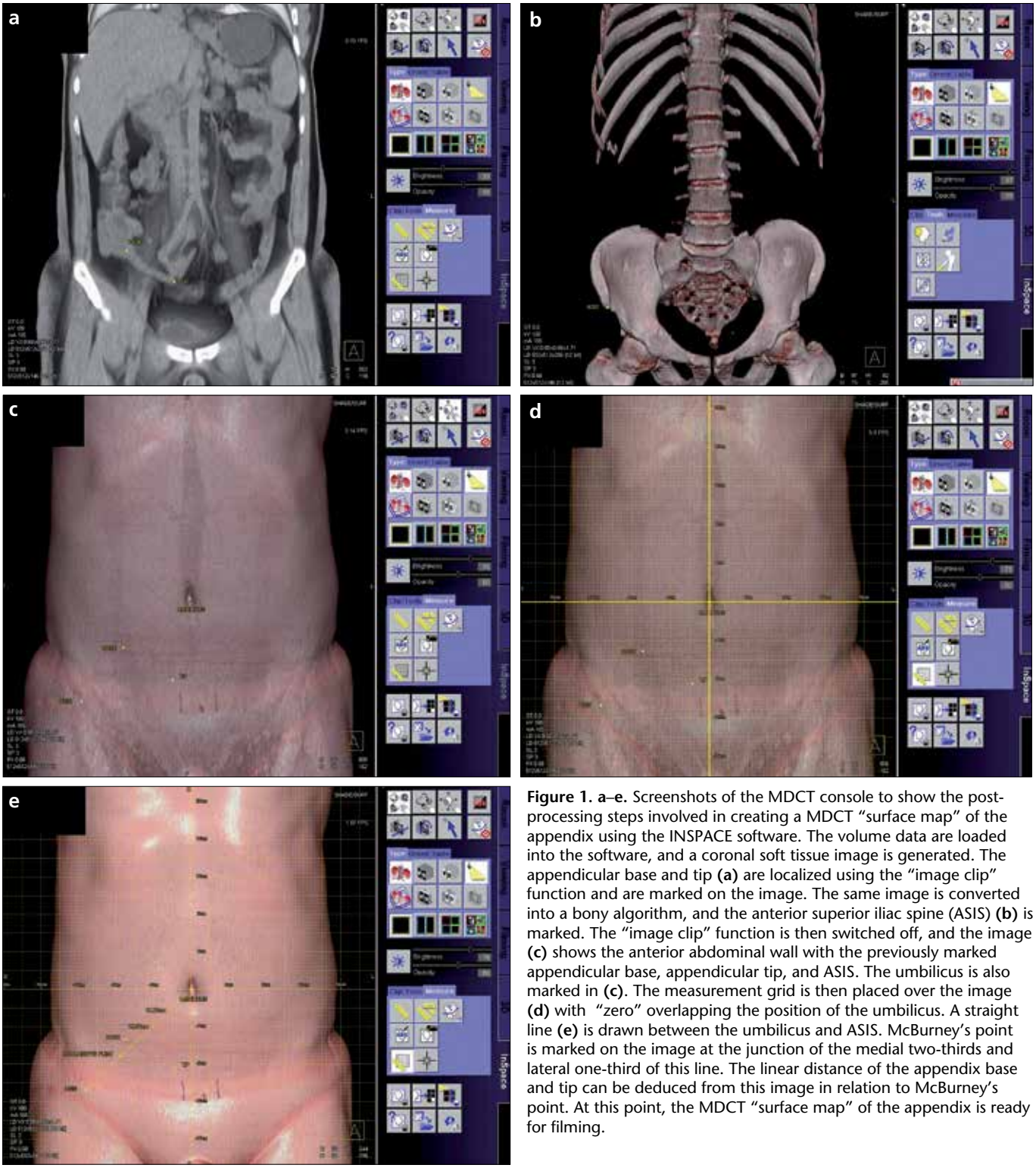

Figure 1. a–e. Screenshots of the MDCT console to show the post-processing steps involved in creating a MDCT "surface map" of the appendix using the INSPACE software. The volume data are loaded into the software, and a coronal soft tissue image is generated. The appendicular base and tip **(a)** are localized using the "image clip" function and are marked on the image. The same image is converted into a bony algorithm, and the anterior superior iliac spine (ASIS) **(b)** is marked. The "image clip" function is then switched off, and the image **(c)** shows the anterior abdominal wall with the previously marked appendicular base, appendicular tip, and ASIS. The umbilicus is also marked in **(c)**. The measurement grid is then placed over the image **(d)** with "zero" overlapping the position of the umbilicus. A straight line **(e)** is drawn between the umbilicus and ASIS. McBurney's point is marked on the image at the junction of the medial two-thirds and lateral one-third of this line. The linear distance of the appendix base and tip can be deduced from this image in relation to McBurney's point. At this point, the MDCT "surface map" of the appendix is ready for filming.

the cranial-medial side of McBurney's point is represented as '+' and along the caudal-lateral side of McBurney's point as '–', followed by the absolute value of distance (cm). The maximum and average variations along each axis were evaluated.

Results

The study group included a total of 74 patients, comprising 40 males and 34 females. Of these, 78% had a normal appendix, while 22% had acute appendicitis. The appendix was optimally identified and the MDCT "surface map" was drawn for all 74 patients. The maximum deviation in the location of the appendicular base was +10.0 cm along the cranio-caudal axis and –4.2 cm along the medio-lateral axis (Fig. 3). The average cranio-caudal deviation

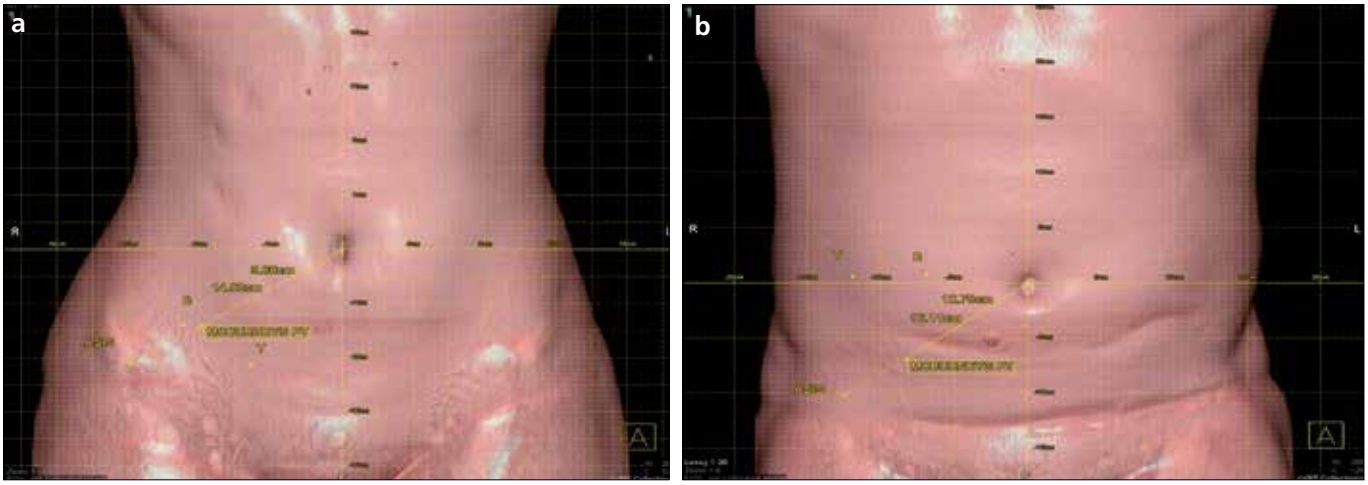

Figure 2. a, b. MDCT "surface map" of appendix in two patients, illustrating the precise location of the appendix with reference to McBurney's point. Appendicular base location was slightly lateral (~10 mm) **(a)** and cranial to McBurney's point (>8 cm) **(b).**

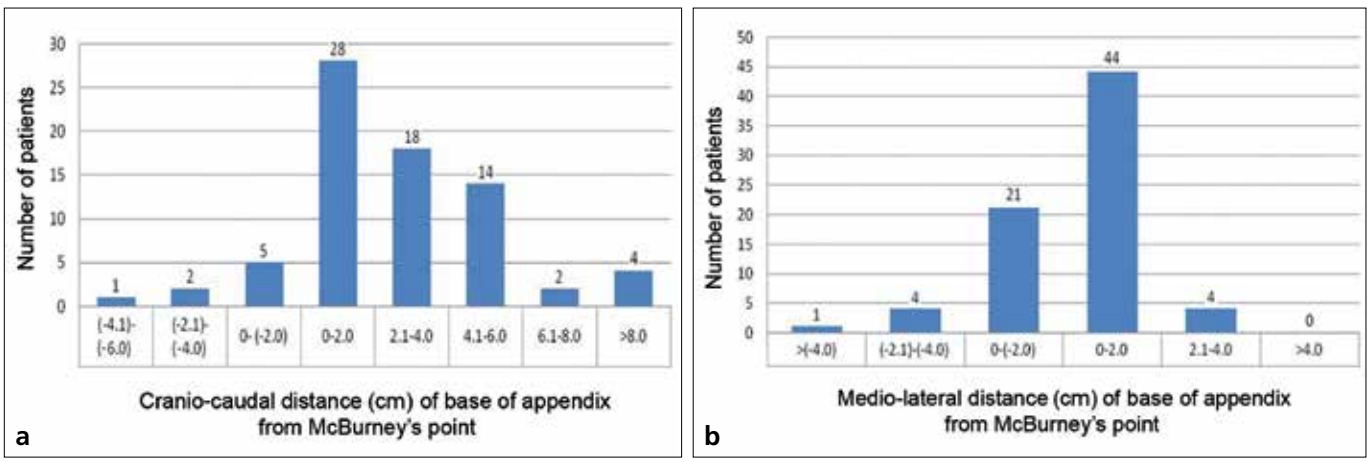

Figure 3. a, b. Bar diagrams showing the variations in the location of the appendicular base with reference to McBurney's point along the cranio-caudal axis **(a)** and medio-lateral axis **(b)**. The average cranio-caudal deviation was +2.79 cm. The maximum deviation in the appendicular base location was +10.0 cm along the cranio-caudal axis and –4.2 cm along the medio-lateral axis.

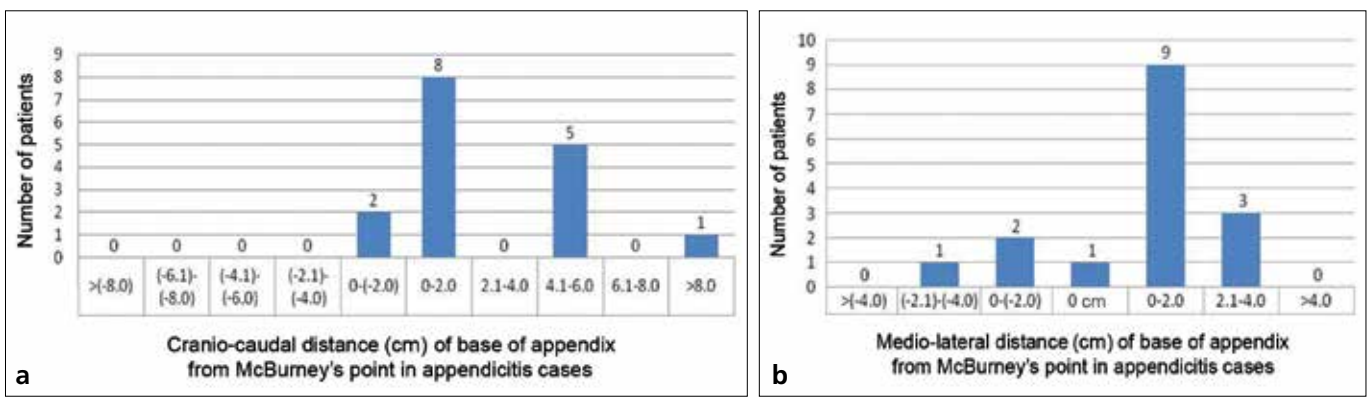

Figure 4. a, b. Bar diagrams showing the variations in the location of the appendicular base with reference to McBurney's point along the cranio-caudal axis **(a)** and medio-lateral axis **(b)** in patients with acute appendicitis.

was +2.79 cm, while the average medio-lateral deviation was +0.146 cm. With respect to McBurney's point, 89% of patients were found to have a cranial deviation and 64.8% a medial deviation.

In a subgroup of 16 patients with acute appendicitis, the maximum deviation was +8.8 cm along the cranio-caudal axis and +3.0 cm along the medio-lateral axis (Fig. 4). The average cranio-caudal deviation in this

subgroup of patients was +2.77 cm, while the average medio-lateral deviation was +0.77 cm. With respect to McBurney's point, 87.5% of patients with an inflamed appendix were found to have a cranial deviation, and 75% a medial deviation, in the location of the appendicular base (Fig. 5).

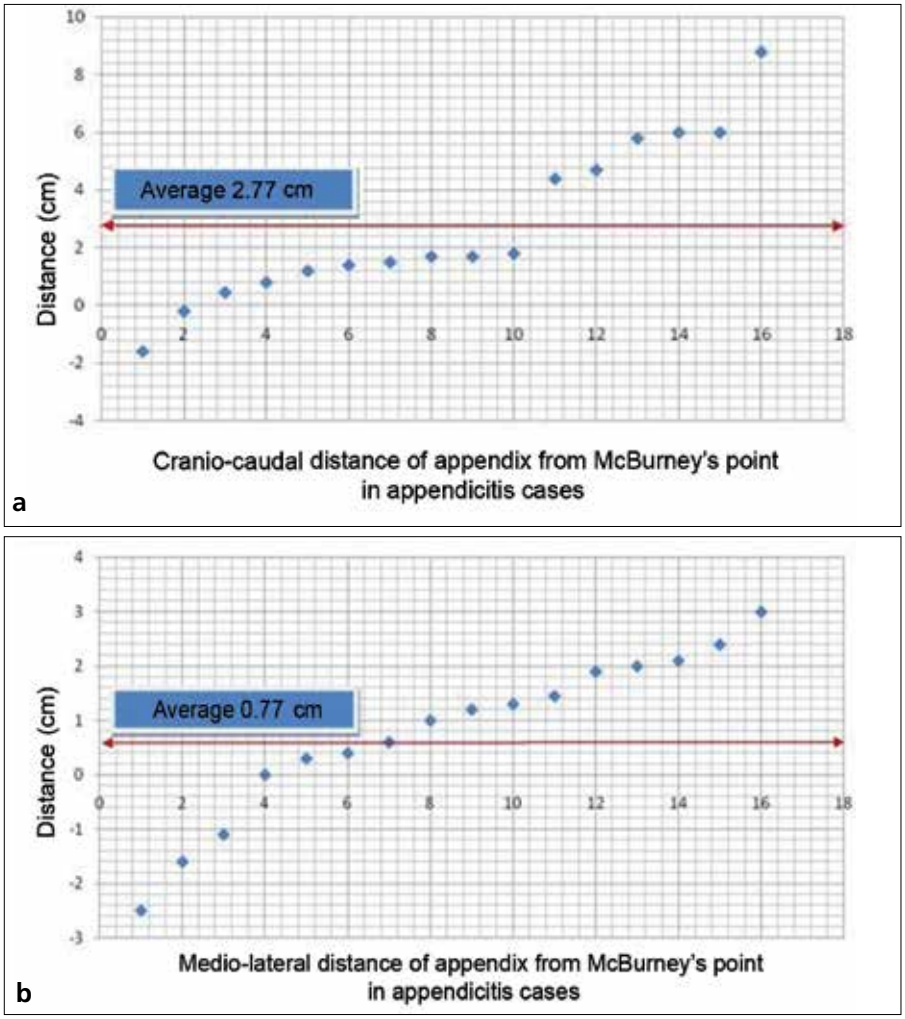

Figure 5. a, b. Scatter diagrams showing variations in the cranio-caudal distance **(a)** and medio-lateral distance **(b)** of the appendicular base from the McBurney's point in patients with acute appendicitis. The average cranio-caudal deviation in this subgroup of patients was +2.77 cm. The average medio-lateral deviation was +0.77 cm.

Discussion

In compliance with previous reports, the present MDCT-based study showed significant variations in the location of the appendicular base with reference to McBurney's point. These variations were more pronounced along the cranio-caudal axis than the medio-lateral axis. In a study based on 275 double contrast barium enemas, 35% of appendix bases were found to lie within 5 cm of McBurney's point, and 15% were >10 cm distal (5). In the present study, 89% of patients had a cranial deviation, and 64.8% a medial deviation, with reference to McBurney's point.

In recent years, there has been a dramatic increase in the use of CT for diagnosis of acute appendicitis. This is predominantly due to the growing body of evidence that suggests lower negative appendectomy rates after increasing the use of MDCT in patients with acute abdomen. One study reported a 93% reduction in negative appendectomy rates with a corresponding increase in the number of patients undergoing a preoperative CT for appendicitis, from 1% to 97.5% over an 18-year period (6).

Apart from effective diagnosis of appendicitis, MDCT is also capable of accurate localization of the appendix. MDCT visualization of the appendix is close to 100%; the appendix was identified in all patients in this study. This information can be effectively conveyed to the operating surgeon in the form of an MDCT "surface map" of the appendix. Due to the use of the standard "3-port technique", preoperative localization is not essential during a laparoscopic appendicectomy. However, this is of significance for open appendicectomies. Decision analysis studies have reported open appendicectomies to be a more economical option for the hospital, and laparoscopic appendicectomies a more economical option for the patient (7). The average operating time of a laparoscopic appendectomy was found to be longer, and also depended significantly upon the experience and expertise of the operating team. An open appendicectomy is usually preferred in patients with cardiac or lung ailments with reduced cardio-pulmonary reserve and in patients with a history of previous lower abdominal surgery, as laparoscopic appendicectomy is a relative contraindication. Pneumoperitoneum during a laparoscopic appendicectomy also increases the risk of general anesthesia-related complications in elderly patients (8). Furthermore, 10% of laparoscopic surgeries may need conversion to open appendicectomies, mainly with high-grade inflammation (9, 10).

In a retrospective analysis of patients with a healthy appendix, Oto et al. (11) reported the influence of MDCT localization using the surface-shaded display technique on the surgeon's decision regarding the site of initial appendectomy incisions. The present study, however, describes the use of an MDCT "surface map" using the VRT to convey this information, which has not been described previously. Surface-shaded display is a process in which the apparent surfaces are identified within the acquired volume and displayed in the image. VRT, on the other hand, incorporates information from the entire volume and is expected to be more accurate. Moreover, the dynamic range is preserved in the VRT image, which contains surface as well as internal details (12, 13). The surface information can be effectively conveyed to the surgeon in the form of a single image on film. An MDCT "surface map" of the appendix is easy to understand and can serve as a "ready reference" for the operating surgeon.

The present study reports variations along the cranial axis in up to 89% of all patients and in 87.5% of patients with acute appendicitis. If the appendix is caudal to the site of incision, then the appendix can be pulled upwards during surgery without incision extension. However, if the appendix shows a cranial variation in location, muscle-cutting extensions are often unavoidable and are associated with a risk of nerve injury, increased postoperative pain or sepsis, and hematoma or hernia formation (14). Variations along the cranial direction are, therefore, of greater surgical relevance compared with other directions.

An MDCT "surface map" of the appendix can therefore facilitate the accurate placement of the initial surgical incision and, thus, minimize the likelihood of incision-extension and other associated complications. The average time required to make the MDCT "surface map" of the appendix was ~5 min, and is therefore not expected to adversely affect the workflow routine even in a busy department. A single MDCT "surface map" file occupies only approximately 70 KB when converted to a JPEG format. Patient obesity and laxity of the anterior abdominal wall, however, constitute an important limitation in the accuracy of MDCT "surface maps". The use of an abdominal compression bandage is likely to minimize this error in this group of patients. Routine use of MDCT "surface maps" in patients with acute appendicitis is certainly feasible without any significant additional burden on the system data base or time penalty. The stated surgical implications are not directly evaluated in this study and are, in fact, based on data extrapolation from existing surgical literature. Prospective case-control studies would be required to validate these stated implications in patients with acute appendicitis. The findings of this study, however, provide enough evidence to recommend the use of an MDCT "surface map" as an effective method of conveying the precise location of the appendix to the operating surgeon.

In conclusion, there are significant variations in the location of the appendix with reference to McBurney's point. The MDCT "surface map" is an effective method for preoperative localization of the appendix and for conveying this information to the operating surgeons using a single additional film. This may help the surgeons identify the optimal site of the initial incision during an open appendicectomy and minimize the likelihood of incision-extensions and associated complications.

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Conflict of interest disclosure

The authors declared no conflicts of interest.

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