ORIGINAL ARTICLE

Eur J Anat, 16 (1): 43-48 (2012)

An analysis of the anatomical trajectory of the inferior epigastric arteries in the era of videolaparoscopic surgery: Is there in fact a "safety zone" for the prevention of iatrogenic lesions?

Douglas Andrade, Débora Abranches, Natália Souza, Raphael Pereira, André Saud, Rafael Prinz, João Pereira-Correia

Department of Anatomy, Faculty of Medicine, Estácio de Sá University, Rio de Janeiro, Brasil

Summary

Despite the fact that the videolaparoscopic method is considered safe, lesions of the nerves and vessels of the anterior abdominal wall can occur during the insertion of the sharp trocars to access the peritoneal cavity due to the rich vasculonervous distribution of that region. With vascular lesions, the inferior epigastric arteries (IEA) are the most affected. Transfusions, rectus abdominis muscle necrosis, hematomas or the formation of abscesses and reoperation have been described as complications. We dissected IEAs from the anterior abdominal walls of 48 adult human cadavers. Four points of reference were determined on the median line, from the pubic symphysis to the umbilicus. Next, the distance of the right and left IEA from all these reference points was evaluated. Computerized morphometric and statistical analyses were performed. Our results suggest that if the insertion of this primary port occurs in the median line, closer to the pubic symphysis, the risk of epigastric lesion will be lower. With respect to the insertion of lateral auxiliary trocars (secondary and tertiary ports) for pelvic videolaparoscopic access, we recommend that these be inserted at least 5 cm away from the median line for the region that runs from the umbilicus to the pubic symphysis. However, because of anatomical variations, we cannot be certain about absolutely safe incision points, although the risk of injury can be reduced through knowledge of the location of the arterial vessels of the abdominal wall. We strongly recommend that, until studies with a higher level of evidence about the detailed distribution of the inferior epigastric arteries in the anterior abdominal wall are conducted, especially in patients under peritoneal insufflation, that imaging methods, such as the sonographic localization of abdominal wall vessels before laparoscopy, should be used, especially in patients with an increased risk of bleeding, the obese, and those with abdominal scarring.

Key words: Epigastric artery – Laparoscopy – Iatrogenic disease – Dissection – Intraoperative complication

Introduction

Videolaparoscopy is considered the gold-standard surgical procedure for treating several abdominal and pelvic diseases. The technique is minimally invasive, since it is performed via small incisions to provide intracav-

Submitted: November 22, 2011
Accepted: January 20, 2012

Correspondence to:
João Antonio Pereira-Correia. Rua Paulo Barreto 28/701, Botafogo, Rio de Janeiro, RJ – Brazil CEP 22.280-010. Phone: 55 21 7868 4349; Fax: 55 21 2595 4976.
Email: joaoapc@ig.com.br

itary access, and it is generally safe, effective, and well-tolerated by patients (Nordestgaard et al., 1995). Nearly all types of abdominal surgery can be performed using the videolaparoscopic method, and it is considered to represent a considerable advance in the areas of general, gynecological, and urologic surgery (Himal, 2002; Yoshida et al., 2010). This procedure has several advantages relative to previously developed procedures, including less post-operative pain, less time in the hospital, better cosmetic results (with smaller scars), a faster return to routine activities, and a lower index of infection from surgical wounds (SAGES, 2007).

Although the videolaparoscopic method is considered safe, lesions of the nerves and vessels of the anterior abdominal wall may occur during the insertion of sharp trocars into the peritoneal cavity owing to the rich vasculonervous distribution of that region. With vascular lesions, it is the inferior epigastric vessels that are most often affected. Lesions of these vessels occur in up to 2% of patients subjected to videolaparoscopic procedures with lateral trocars (Bergqvist and Bergqvist, 1987; Hurd et al., 1993; Schafer et al., 2000; Saber et al., 2004). In urologic laparoscopic surgery, vascular injuries account for approximately half of the total number of complications (Gill et al., 1998).

Injury of the inferior epigastric artery (IEA) may have different clinical presentations. During laparoscopy, bleeding may be manifested as external oozing around the port site or internal dripping along the shaft of the cannula into the abdominal cavity. The injury may initially go unrecognized, due to the temporary tamponade produced by the cannula and pneumoperitoneum, and then appear later as a hematoma or pseudoaneurysm (Verbist, 1997). Transfusions, rectus abdominis muscle necrosis, hematomas, or the formation of abscesses and subsequent reoperation to control bleeding have also been described as complications of vascular lesions (Heppert et al., 1995; Chapron et al., 1997; Fruhwirth et al., 1997).

The ideal approach to avoid lesions in superficial blood vessels during videolaparoscopy is to visualize them directly by transillumination. However, in the great majority of cases, only superficial epigastric vessels can be detected using this technique (Hurd et al., 1994; Quint et al., 1996; Tomacruz et al., 2001). Hence, there is a need to study reference points on the abdominal surface in order to prevent inadvertent lesions in these vessels. In our study, we evaluated reference points on the surface of the abdomen that can be used to reduce the risk of iatrogeneses of the IEA during videolaparoscopic access.

Materials and Methods

From June 1 to July 31, 2011, we dissected the anterior abdominal walls of 48 adult human cadavers that had been preserved in a 5% formaldehyde solution. The specimens came from the Anatomical Laboratory of the Faculty of Medicine of the Estácio de Sá University (Rio de Janeiro, RJ, Brazil). Cadavers for which the cause of death involved the abdomen or that had a macroscopic anomaly in the anterior abdominal wall, including hernias, were excluded.

Dissection of the IEAs in the anterior abdominal wall was performed via a bilateral subcostal incision on the anterior abdominal axillary lines; the tissue was then peeled back onto the symphysis pubis to expose the region behind the anterior abdominal wall. The parietal peritoneum and the posterior sheath of the rectus abdominis muscle were removed so that the IEAs and the rectus abdominis muscle could be visualized, taking care to preserve the connection from the IEAs to the muscles.

As shown in Figure 1, two points of reference were established on the midline: the symphysis pubis and the umbilicus (green arrows). From these, three more points of reference were created: the midpoint between the symphysis pubis and the umbilicus (demarcated with a red arrow), and two additional points identified by yellow arrows, which were situated halfway between the green and red arrows. The distance from the right and the left IEA from each of these reference points was then evaluated (Fig. 1).

The dissected anatomical specimens were photographed using a high-resolution digital camera (Sony™ Cyber-Shot™ DSC-W320 14.1 megapixels). Morphometric analysis was performed using Image Pro Plus™ software, version 4.5, from Media Cybernetics™ (Bethesda, MD, USA). Normality analysis was performed using the Kolmogorv-Smirnov test. For data with a Gaussian distribution, a

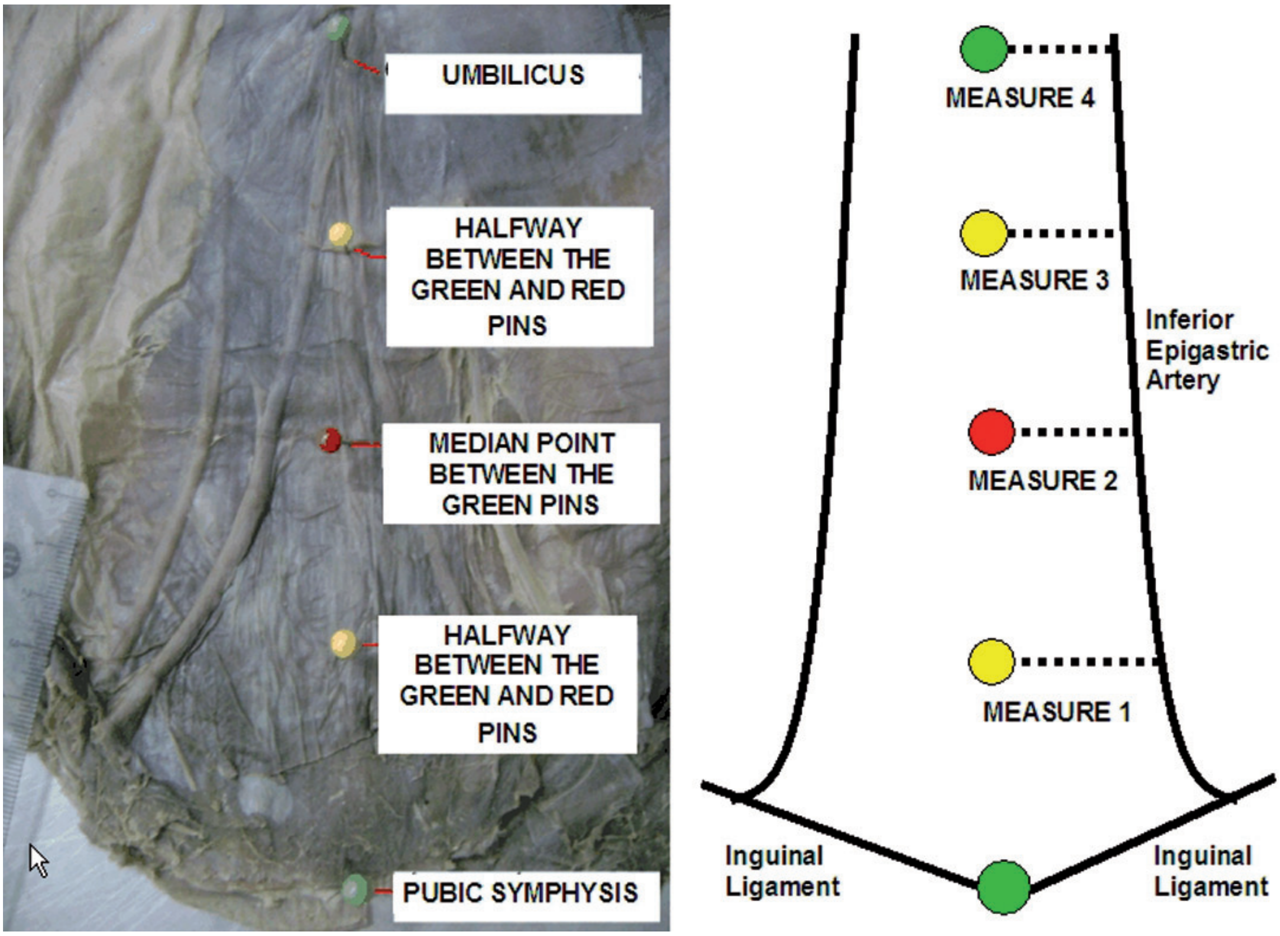

Fig. 1. Photograph (left) and diagram (right) of an abdominal wall. The pubic symphysis and the umbilicus are represented by green pins. From these, three more points of reference were created: the median point between the green pins, demarcated with a red pin, and two further points, identified by yellow pins, which are situated halfway between the green and red pins. Next, the distance of the right and left IEA from all these reference points was evaluated (measurement 1, measurement 2, measurement 3 and measurement 4).

comparative evaluation of the groups was performed using Student's t-test. For data with a non-Gaussian distribution, the Mann-Whitney test was employed, using $p < 0.01$ as the value for statistical significance. Statistical analysis was performed using a commercially available data analysis program: GraphPad Prism™, version 5 (La Jolla, CA, USA).

Results

Demographic data for all cadavers were available. The mean age at the time of death (range) was 72 years (65-79 years); mean height was 166 cm (154-178 cm); mean weight was 55 kg (42-81 kg); and the mean body mass index (BMI) was 20 kg/m^2 (17.7-25.6 kg/m^2). Forty-six of the cadavers were male, and two were female. Half of the cadavers were of mixed race: 15 were black, and 9 were white. All of the cadavers were of Brazilian nationality. The results for the measurements in relation to the reference points on the anterior abdominal wall, as well as the comparisons between them, are shown in Tables 1 and 2.

	Right		Right		p-value
	Range (cm)	Average (cm)	Range (cm)	Average (cm)	
Measure 1	2.7 – 8.5	5.1	1.6 – 11.2	5.1	p=0.31
Measure 2	2.4 – 6.8	4.5	1.6 – 8.8	4.7	p=0.47
Measure 3	2.5 – 6.8	4.1	2.3 – 9.2	4.3	p=0.45
Measure 4	2.6 – 7.3	4.3	2.1 – 9.9	4.6	p=0.20

Table. 1. Results for the measurements in relation to the reference points on the anterior abdominal wall, as well as the laterality comparisons between them. The measurements did not differ significantly between groups.

Comparisons between the measurements	p-value
Measurement 1 x Measurement 2	p < 0,01
Measurement 1 x Measurement 3	p < 0,01
Measurement 1 x Measurement 4	p < 0,01
Measurement 2 x Measurement 3	p = 0,48
Measurement 2 x Measurement 4	p = 0,07
Measurement 3 x Measurement 4	p = 0,18

Table. 2. Results for the comparisons between the measurements related to the distances of the right and left IEA from reference points.

Discussion

Iatrogenic lesions that occur at the moment when videolaparoscopic trocars are inserted most often affect the vessels and nerves of the anterior abdominal wall. With respect to these vascular lesions, we have observed that IEA lesions are frequently related to abdominal transfixation by sharp trocars (primary, secondary, and tertiary).

Standard anatomy textbooks describe the origin of the IEA in detail and give a brief description of its course. IEA is traditionally considered to be located in the anterior abdominal wall, parallel to the rectus abdominis muscle and originating from the external iliac artery (Bouchet and Cuilleret, 1979). However, the information available to date in terms of detailed morphometric analysis shows that the IEA trajectory varies considerably. In the most comprehensive study of the arterial supply to the anterior abdominal wall carried out to date (115 cadavers), Milloy et al. (1960) documented large variations in the position and branches of the IEA. The distance from the symphysis pubis to the point where the IEA crossed the lateral border of the rectus abdominis muscle was found to range from as little as 0 cm to as much as 10 cm. Meanwhile, other studies performed on cadavers have reported the mean distance between the IEA to the midline to be between 4.5 cm and 6.1 cm (Epstein et al., 2004). Tomographic studies of the abdominal wall *in vivo* have shown a variation in this average distance of 4.7 to 5.3 cm (Hurd et al., 1994; Saber et al., 2004; Sriprasad et al., 2006). Examinations of umbilicus height have revealed that the IEAs average distance from the umbilicus varies from 4.6 cm to 5.4 cm (Hurd et al., 1994; Balzer et al., 1999; Epstein et al., 2004; Saber et al., 2004; Sriprasad et al., 2006; Rahn et al., 2010). In our analysis, we adopted four reference points to study IEA trajectories in the infraumbilical region. This area was selected because it corresponds to the main route of access for pelvic videolaparoscopic procedures. We observed mean IEA-umbilicus distances that were slightly less than in the aforementioned studies, that is, 4.3 cm for the right IEA and 4.6 cm for the left IEA. This difference could possibly be explained in terms of slight physical differences between Brazilians cadavers versus Europeans and North-Americans cadavers. In the region immediately above the symphysis pubis ("measurement 1"), however, our findings were in close agreement with prior studies, with an average distance of 5.1 cm, bilaterally.

Our statistical analysis showed that after going beyond the region of "measurement 1" (just above the symphysis pubis), the vessels assumed a more medial trajectory and remained on course without any changes up to the umbilicus; we did not find any statistically significant variances in measurements 2, 3, and 4. The proximity of the epigastric vessels to the umbilicus is clearly a risk factor when the umbilicus is used for the primary port, particularly when the Veress needle is inserted blindly (Vilos et al., 2007). Therefore, we believe that if this primary port is inserted on the midline, close to the symphysis pubis, there will be a lower risk of epigastric lesion. Of course, when this more inferior access is to be adopted it is recommended that the bladder first be emptied using a vesical catheter.

With respect to pelvic videolaparoscopic access, it has been recommended, based on studies of cadavers, that lateral auxiliary trocars (secondary and tertiary ports) be inserted at least 5-6 cm away from the midline, in the region between the umbilicus and the symphysis pubis (Hurd et al., 1994; Balzer et al., 1999; Epstein et al., 2004; Saber et al., 2004; Sriprasad et al., 2006; Rahn et al., 2010). Our results are in agreement with this recommendation given that the average distance between the IEAs and the midline ranged from 4.1 to 5.1 cm. It should be emphasized, however, that even when respecting this "safety zone," the surgeon should remain attentive to possible anatomical variations in the trajectory of this vessel This is because, in our evaluation, some vessels were found as close as 2.5 cm and as far away as 8.5 cm from the midline.

Despite the fact that we used a substantial number of cadavers relative to other anatomic studies, one limitation of our study is that we used cadavers with a BMI almost exclusively below 25 kg/m^2 (1 subject had a BMI = 25.6 kg/m^2). That is, although there is a current pandemic of excess body weight and obesity, which also affects the Brazilian population (Gigante et al., 2011), we did not examine the influence of excess weight/obesity on IEA location. Studies that have taken these aspects into consideration have provided interesting results. Using tomographic images, Saber et al. performed a comparative analysis of the course of IEAs in individuals with a BMI above and below 25 kg/m^2 and found that the average distance between IEAs and the midline was 0.3 cm and 0.7 cm greater in the higher BMI group than in the lower BMI group at the level immediately above the symphysis pubis and the umbilicus, respectively (Saber et al., 2004). One study that employed ultrasonography and dopplerfluxometry of the epigastric vessels in patients with a normal/average BMI, although higher than the BMI range included in our study, also described a slight lateral distancing in the trajectory of the epigastric vessels in the higher BMI subjects, suggesting that a greater abdominal circumference, and hence likely with more adipose accumulation, may be associated with IEAs being situated further from the midline (Hurd et al., 1994). It should be underscored, however, that as far as we know, our evaluation is the first analysis of the trajectory of IEAs in Brazilian cadavers and that other studies that consider this variation should be carried out in the future.

Another potential criticism of our study is that we performed our analysis of the cadavers without peritoneal insufflation, a condition inherent to videolaparosopic procedures. The preservation of human material in formaldehyde solution, however, limits this type of observation because of the reduction in the distensibility of the tissues caused by the preservation solution, making it impossible to create an ideal pneumoperitoneum. To overcome this fixative-imposed condition, Rahn and colleagues analyzed the variation of the position of abdominal reference points after producing peritoneal insufflation in 11 unembalmed female cadavers (Rahn et al., 2010). With insufflation of the abdominal cavity, the distances moved by points on the skin overlying landmarks of interest were highly variable. The McBurney point moved 8.2 mm laterally and 3.1 mm inferiorly, while the point on the skin overlying the anterior superior iliac spine moved 10.5 mm laterally and 8.8 mm inferiorly. However, the distribution of the inferior epigastric vessels was not evaluated in these cadavers. Hurd et al. (2003) conducted a rather interesting study analyzing the distribution of the IEAs in 105 women undergoing laparoscopy for tubal sterilization, infertility, pelvic masses, or pelvic pain. At the level where the vessels were evaluated (5-8 cm above the symphysis pubis), their courses were relatively parallel and did not cross. There was a linear relationship between the relative location of the superficial and inferior epigastric vessels and BMI, such that the inferior vessels were more likely to be lateral to the superficial vessels in heavier women. Nevertheless, it should be emphasized that even with laparoscopic vision, the inferior epigastric vessels could not be identified in 20% of patients. When transillumination was used to investigate the IEAs, the rate of failure practically doubled, rising to almost 40%. Furthermore, the success rate was worse in dark-skinned patients (30%) and the obese (75%).

Based on our study, we suggest the use of videolaparoscopic trocar insertion points for pelvic access in order to increase the safety of the technique. Although our results cannot absolutely define safe incision points due to anatomical variations, the risk of injury can be reduced by knowing the location of the arterial vessels of the abdominal wall. Until studies addressing the detailed distribution of IEAs in the anterior abdominal wall with a more supportive evidence are conducted, especially in patients under peritoneal insufflation, we strongly recommend that abdominal wall vessels be localized by imagining methods, such as sonography, before laparoscopy is carried out, particularly in patients with an increased risk of bleeding, the obese, and those with abdominal scarring.

References

Balzer KM, Witte H, Recknagel S, Kozianka J, Waleczek H (1999) Anatomic guidelines for the prevention of abdominal wall hematoma induced by trocar placement. *Surg Radiol Anat,* 21: 87-89.

Bergqvist D, Bergqvist A (1987) Vascular Injuries during gynecological surgery. *Acta Obstet Gynaecol Scand,* 66: 19-23.

Bouchet A, Cuilleret J (1979) *Anatomia descriptiva, topografica y funcional: abdomen*. Panamericana, Buenos Aires.

Chapron CM, Pierre F, Lacroix S, Querleu D, Lansac J, Dubuisson JB (1997) Major vascular injuries during gynecologic laparoscopy. *J Am Coll Surg,* 185: 461-465.

Epstein J, Arora A, Ellis H (2004) Surface anatomy of the inferior epigastric artery in relation to laparoscopic injury. *Clin Anat,* 17: 400-408.

Fruhwirth J, Koch G, Mischinger HJ, Werkgartner G, Tesch NP (1997) Vascular complications in minimally invasive surgery. *Surg Laparosc Endosc,* 7: 251-254.

Gigante DP, De França GV, Sardinha LM, Iser BP, Meléndez GV (2011) Temporal variation in the prevalence of weight and obesity excess in adults. *Rev Bras Epidemiol,* 14 Suppl 1: 157-165.

Gill IS, Clayman RV, Albala DM, Aso Y, Chiu AW, Das S, Donovan JF, Fuchs GJ, Gaur DD, Go H, Gomella LG, Grune MT, Harewood LM, Janetschek G, Knapp PM, Mcdougall EM, Nakada SY, Preminger GM, Puppo P, Rassweiler JJ, Royce PL, Thomas R, Urban DA, Winfield HN (1998) Retroperitoneal and pelvic extraperitoneal laparoscopy: An international perspective. *Urology,* 52: 566-571.

Heppert V, Holz F, Winkler H, Wentzensen A (1995) Necrosis of the rectus abdominis muscle: complication after ilioinguinal approach. *Unfallchirurg*, 98: 98-101.

Himal HS (2002) Minimally invasive (laparoscopic) surgery. ***Surg Endosc,*** 16: 1647-1652.

Hurd WW, Pearl ML, Delancey JO, Quint EH, Garnett B, Bude RO (1993) Laparoscopic injury of abdominal wall blood vessels: a report of three cases. *Obstet Gynecol,* 82:673-676.

Hurd WW, Bude RO, Delancy JoL, Newman JS (1994) The location of abdominal wall blood vessels in relationship to abdominal wall landmarks apparent at laparoscopy. *Am J Obstet Gynecol,* 171: 642-646.

Hurd WW, Amesse LS, Gruber JS, Horowitz GM, Cha GM, Hurteau JA (2003) Visualization of the epigastric vessels and bladder before laparoscopic trocar placement. *Fertil Steril,* 80: 209-212.

Milloy FJ, Anson BJ, McAfee DK (1960) The rectus abdominis muscle and the epigastric arteries. *Surg Gynecol Obstet,* 110: 293-302.

Nordestgaard AG, Bodily KC, Osborne RW JR, Buttorff JD (1995) Major vascular injuries during laparoscopic procedures. *Am J Surg,* 169: 543-545.

Quint EH, Wang FL, Hurd WW (1996) Laparoscopic transillumination for the location of anterior abdominal wall blood vessels. *J Laparoendosc Surg*, 6: 167-169.

Rahn DD, Phelan JN, Roshanravan SM, White AB, Corton MM (2010) Anterior abdominal wall nerve and vessel anatomy: clinical implications for gynecologic surgery. *Am J Obstet Gynecol,* 202: 234.e1-5.

Saber AA, Meslemani AM, Davis R, Pimentel R (2004) Safety zones for anterior abdominal wall entry during laparoscopy: a CT scan mapping of epigastric vessels. *Ann Surg,* 239: 182-185.

Sages – Society of American Gastrointestinal and Endoscopic Surgeons (2007) Guidelines for diagnostic laparoscopy. Available from: http://www.sages.org/publication/id/12/

Schafer M, Lauper M, Krahenbuhl L (2000) A nation's experience of bleeding complications during laparoscopy. *Am J Surg,* 180: 9-14.

Sriprasad S, Yu DF, Muir GH, Poulsen J, Sidhu PS (2006) Positional anatomy of vessels that may be damaged at laparoscopy: new access criteria based on CT and ultrasonography to avoid vascular injury. *J Endourol,* 20: 498-503.

Tomacruz RS, Bristow RE, Montz FJ (2001) Management of pelvic hemorrhage. *Surg Clin North Am,* 81: 925-948.

Verbist J (1997) Pseudoaneurysm of the inferior epigastric artery. *Acta Chir Belg*, 97: 196-198.

Vilos GA, Ternamian A, Dempster J, Laberge PY (2007) Laparoscopic entry: a review of techniques, technologies, and complications. *J Obstet Gynaecol Can*, 29: 433-465.

Yoshida M, Furukawa T, Morikawa Y, Kitagawa Y, Kitajima M (2010) The developments and achievements of endoscopic surgery, robotic surgery and function-preserving surgery. *Jpn J Clin Oncol,* 40: 863-869.