Surg Endosc (2011) 25:1489–1494
DOI 10.1007/s00464-010-1419-x

Single-incision laparoscopic liver resection

Sébastien Gaujoux · T. Peter Kingham · William R. Jarnagin · Michael I. D'Angelica · Peter J. Allen · Yuman Fong

Received: 14 June 2010 / Accepted: 2 September 2010 / Published online: 26 October 2010

Abstract
Background Laparoscopic liver surgery has become a safe and effective approach to the surgical management of liver disease. Recently developed, single-port-access surgery is of growing interest in an attempt to minimize abdominal wall trauma. Various abdominal procedures have already been performed via single-port access, but to date, single-port-access surgery has never been reported for liver resection.
Methods One patient underwent laparoscopic fenestration of a giant (30-cm) right hepatic cyst. Three patients underwent left liver resection through a single port for isolated liver metastasis located in segments 3/4B, 2/3, and 3/4B, respectively, and a cirrhotic patient underwent a 4B wedge resection for hepatocellular carcinoma.
Results Each procedure was performed through a single 40-mm Gelport. No supplemental ports were required. The liver was transected using a combination of LigaSure harmonic scalpels and staplers. In one case, parenchymal transection was intraoperatively prepared by a zone of microwave ablation along the line of intended division. The total operative times for the aforementioned five patients were 140,110, 110, 120, and 55 min, respectively. The respective blood losses were 20, 50, 50, 25, and 50 ml, and the overall size of the incision was 50 mm in each case. The postoperative courses were uneventful, and each patient was discharged on postoperative day 2.
Conclusion This preliminary experience suggests the technical feasibility and safety of left liver wedge resection through single-port access in terms of intra- and postoperative results. Additional experiences are mandatory to assess the viability of this emerging technique and to expand its application to additional right liver resections.

Keywords Liver resection · Single-incision laparoscopic surgery · Single-port-access surgery

S. Gaujoux · T. P. Kingham · W. R. Jarnagin · M. I. D'Angelica · P. J. Allen · Y. Fong (✉)
Department of Surgery, Memorial Sloan-Kettering Cancer Center, 1275 York Avenue, New York, NY 10065, USA
e-mail: fongy@mskcc.org

Laparoscopic surgery has become the standard approach for many abdominal procedures and can be considered one of the major technical advances in surgery over the past 20 years. The laparoscopic approach currently is widely used for cholecystectomy, antireflux surgery, splenectomy, adrenalectomy, and colorectal surgery, among other procedures. Its potential advantages over open procedure include a lower morbidity rate, less postoperative pain, a shorter hospital stay, faster recovery, and a cosmetic advantage. Nevertheless, initially, many have been reluctant to use laparoscopy for liver resections due to the complexity of such procedures and the potential for life-threatening hemorrhage.

Since the first reported use of laparoscopic liver surgery in 1992 [1], it has been increasingly used [2–8]. Studies from several centers have confirmed that it is technically feasible and safe and that its oncologic results are comparable with those for open resection [6–11]. A recent international position on laparoscopic liver surgery, the Louisville Statement [10], has determined laparoscopic liver surgery to be a safe and effective approach for the management of surgical liver disease in the hands of trained surgeons with experience in hepatobiliary and laparoscopic surgery.

Recently, in an attempt to decrease abdominal wall trauma and visible scar, single-port-access surgery has

been developed, and this field is now rapidly evolving. Various abdominal procedures have been performed already through single-port access, including appendectomy [12], cholecystectomy [13], gastrojejunostomy [14], splenectomy [15], sleeve gastrectomy [16, 17], adjustable gastric band placement [18], and colonic surgery [19–27]. To the best of our knowledge, single-port-access surgery has never been reported for liver resection. In this report, we describe the first liver resections through a single port.

Patients and methods

Patients

Case 1

An otherwise healthy 62-year-old woman presented with increasing abdominal distention, decreasing appetite, and weight loss. Her workup showed a large (30 cm) benign-appearing cyst occupying the entire right side of her abdomen. Her body mass index (BMI) was 20.1 kg/m^2.

Case 2

A 52-year-old woman presented with a solitary 2-cm ovarian cancer liver metastasis in the 3/4B segment, documented on magnetic resonance imaging (MRI) and on a positron emission tomography (PET)/computed tomography (CT) scan. She previously had undergone a total abdominal hysterectomy with bilateral salpingo-oophorectomy including omentectomy and lymph node dissection with adjuvant intraperitoneal chemotherapy. Surgical resection was indicated after systemic chemotherapy and stable disease for at least 6 months. Her BMI was 27.1 kg/m^2.

Case 3

A 52-year-old woman presented with a solitary 1.3-cm colon cancer liver metastasis in segment 3, documented on CT scan, PET/CT scan, and MRI. She had previously undergone laparoscopic right hemicolectomy and had no other comorbidity. Surgical resection was indicated after nine cycles of folinic acid (leucovorin), 5-fluorouracil (5-FU), and oxaliplatin (FOLFOX)-Avastin (bevacizumab) chemotherapy, with a partial response. Her BMI was 31.2 kg/m^2.

Case 4

A 57-year-old man presented with a sigmoid colon cancer involving a unique 1.5-cm segment 3/4B synchronous liver metastasis. After laparoscopic sigmoid resection followed by six cycles of FOLFOX-6 chemotherapy, with a partial response, surgical resection was planned. His BMI was 29.9 kg/m^2.

Case 5

A 62-year-old man with Child A alcoholic cirrhosis presented with a solitary 2-cm hepatocellular carcinoma in the 4B segment, as documented on ultrasonography, MRI, and CT scan. His medical history was significant for alcoholic cirrhosis, encephalitis, type 2 diabetes, and high blood pressure. His BMI was 27.5 kg/m^2.

All five patients gave informed consent for the laparoscopic surgical approach.

Surgical technique

The following techniques were common to all five procedures. Surgery was performed through a single supraumbilical port site using a 40-mm umbilical port (Gelport; Applied Medical Resources, Rancho Santa Margarita, CA, USA) placed through an open approach. The incision was vertical and included the umbilicus in the noncirrhotic patients. This allowed both easy control of the porta hepatitis if needed and a perfect visualization of the liver transection plan.

Before placement of the Gelport, the porta hepatis was controlled under direct visualization with a Vesocclude device (Vesocclude Medical, Raleigh, NC, USA) to allow application of the Pringle maneuver as needed. A 10-mm deflectable-tip laparoscope (LTF-VH Deflectable-Tip Video Laparoscope; Olympus, Center Valley, PA, USA) was used.

In general, four standard laparoscopic ports were placed through the Gelport system (Applied Medical), as shown in Figs. 1 and 2. The ports can be arranged as in Fig. 2A, with the camera on the top along the line of liver transection. Typically, bowel graspers can be used straight (Fig. 3) or crossed to allow simultaneous traction and countertraction (Fig. 4). A cutting instrument, either an ultrasonic shear or a LigaSure instrument (Covidien Inc, Boulder, CO, USA), can be used through the other center port (Fig. 4). The entire Gelport then can be turned quickly to configuration B or C according to the surgical constraints. In these positions, a single grasper can be used for traction. The ligamentous attachments of the liver function can be used as countertraction. The cutting instruments then can be used alternatively from the top or bottom as necessary to achieve the optimal angle for parenchymal transection (Fig. 3). When vascular pedicles or hepatic veins are encountered, dissecting clamps and suturing devices also can be introduced through these ports for isolation and ligation of vessels.

Fig. 1 Intraoperative view of the Gelport system with standard laparoscopic ports (*upper panel*), allowing palpation, ultrasonography, or immediate control of any major bleeding site if necessary

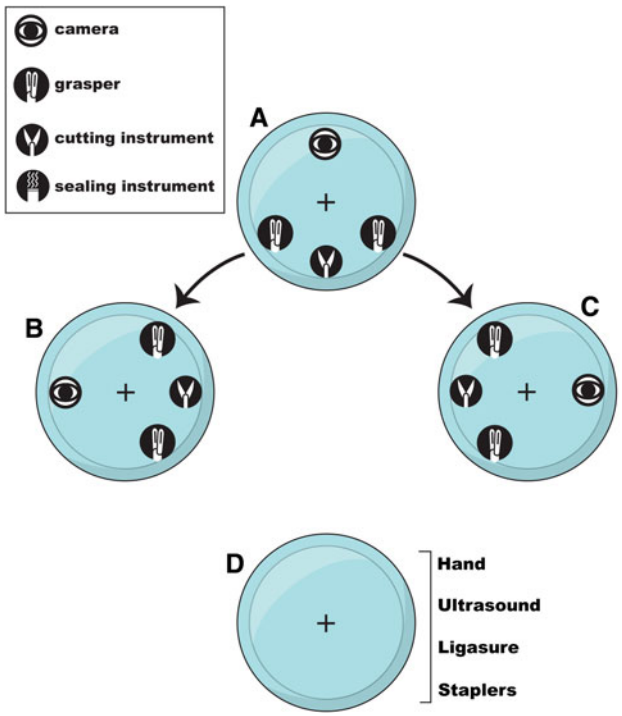

Fig. 2 Various arrangements of the ports through the Gelport. **A** The camera is in the center, along the line of liver transection. **B**, **C** Rotation to the right or the left of the entire Gelport. **D** Various uses of the central access port of the Gelport

The additional advantage of performing single-port-access surgery through the GelPort is that the hand-access port allows for palpation of any internal structure if

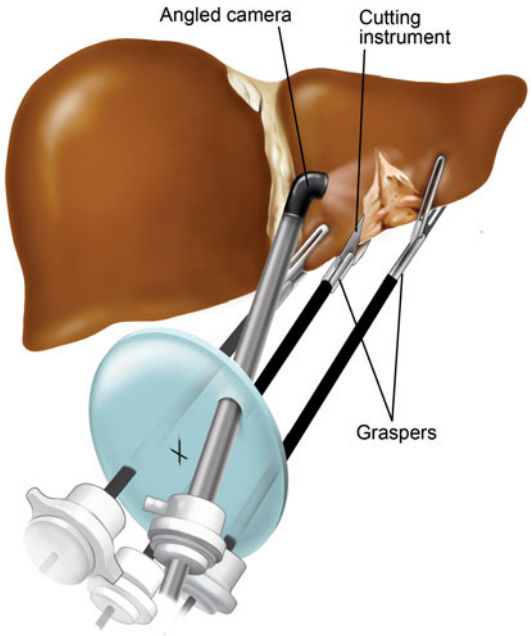

Fig. 3 Cutting instruments used from the top or bottom as necessary to achieve the best angle for parenchymal transection

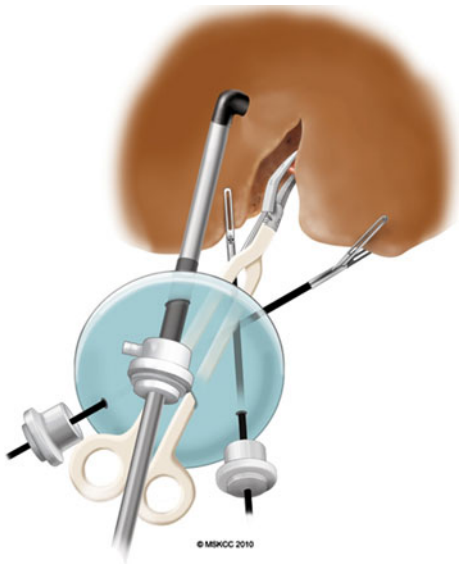

Fig. 4 Large instruments such as standard ultrasound probes, Ligasure devices, and staplers introduced through the head access port

necessary, ultrasonography using a standard probe, immediate control of any major bleed site if necessary, and use of large instruments such as standard ultrasound probes, LigaSure devices (Fig. 4), and staplers.

Specific teaching points from case 1

A large hepatic cyst such as the one in this case carries a high risk of recurrence if only a small section is unroofed. These

cysts often require dissection and protection of adherent structures, followed by extensive excision of the cyst wall. Ability to rotate the GelPort and direct the instruments toward many parts of the abdomen and pelvis greatly facilitates the dissection of the cyst. Ability to use the LigaSure Impact instrument (Covidien Inc), originally designed for open surgery and not fitting through any standard trocar, greatly facilitates safe cyst fenestration. In this case, although an incision larger than 10 mm was not necessary most of the time for retrieval of the specimen after roof cyst resection, the choice of a single-port access through a midline incision was made because the volume of such a cyst would not allow us safe insertion of ports in this patient.

Specific teaching points from case 2

This patient had ovarian cancer and previously had undergone an abdominal debulking procedure through a midline incision. A direct cutdown allowed freeing of adhesions around the site for safe introduction of the GelPort. The instruments and camera were first directed toward the lower abdomen for a complete laparoscopic restaging of the abdomen and pelvis before turning of the entire GelPort to allow for the single-port-access hepatectomy.

Specific teaching points from case 3

Intraoperatively, before parenchymal transection, a zone of heat coagulative necrosis was created along the line of intended liver parenchyma division, with microwave ablation guided by laparoscopic and ultrasonographic imaging. The microwave probe was introduced through the GelPort, and no additional transcutaneous punctures were necessary. In this case, we used a cooled laparoscopic microwave probe. However, because the introduction of the probe is through the GelPort and not through the skin, a noncooled probe would have been acceptable, involving a minimal risk of thermal injury to skin or muscle.

Specific teaching points from case 4

This patient had undergone a previous laparoscopic sigmoidectomy, and no adherences were observed during the insertion of the single-port-access device in supraumbilical position. Overall, this all-laparoscopic approach for colorectal liver metastasis avoids a xyphopubian incision, allowing a fast postoperative recovery and a rapid initiation of adjuvant chemotherapy. Additionally, with increasing experience, the specific constraints of single-port-access surgery (i.e., the lack of triangulation, crowding of instruments over the access port, and the chopstick effect) and the cross-hand approach become much easier to handle. Unfortunately, the hand port incision could not have been made at the sigmoid colon specimen retrieval site because it was too low, in suprapubic position. Nevertheless, we believe that in selected cases, such as synchronous left-sided colonic metastasis, a combined resection of both the metastasis and the primary colonic lesion would be possible through the single-port-access procedure.

Specific teaching points from case 5

This patient had alcoholic cirrhosis with moderate portal hypertension. A supraumbilical incision avoided the umbilical varices, the transection of which could lead to bleeding or increased portal hypertension. Ultrasonography and palpation allowed assessment for the existence of regenerative nodules and biopsy if needed. The umbilical ligament was not transected and was used for exposure.

Intra- and Postoperative outcome

In all five cases, the liver resection was undertaken successfully without intra- or postoperative complication. There was no need for additional ports. No suction drain was left in place. The total operative times were 110, 110, 140, 120, and 55 min, respectively. The respective blood losses were 50, 50, 20, 25, and 50 ml.

The postoperative courses in all five cases were uneventful, without ascites development in the cirrhotic patient. The patients were ambulating and tolerating a regular diet the next day. All were discharged on postoperative day 2.

The patients experienced only minimal pain. Pathologic examination of the specimens showed a benign cyst in case 1, a poorly differentiated ovarian serous carcinoma liver metastasis in case 2, a metastatic colorectal cancer in case 3, a well-differentiated colorectal liver metastasis in case 4, and a 2-cm moderately differentiated hepatocellular carcinoma in case 5. The margins were negative for the cancers, and tumors showed no disruption.

Discussion

Single-port-access surgery was first described by Piskun and Rajpal [28] for cholecystectomy in the late 1990s. To date, single-port-access surgery has been performed for various abdominal and extraabdominal surgical procedures [12–18, 29–32]. In this report, we describe the first five single-port-access procedures for liver resections. This procedure respects oncologic principles, and with the adjunct of some artifact such as microwave application along the line of intended liver parenchyma division, it appears to be safe and feasible for wedge left liver resection or cyst fenestration.

Currently, laparoscopic liver surgery is a safe and effective approach to the surgical management of liver disease in the hands of trained surgeons with experience in hepatobiliary and laparoscopic surgery, as recently stated in the Louisville Statement [10]. Moreover, according to a multi-institutional international report [9], laparoscopic liver resection for colorectal metastasis appears to be safe, feasible, and oncologically comparable with open liver resection for both minor and major liver resections [6–11]. This applies even with prior intraabdominal operations for carefully selected patients when performed by experienced surgeons, as previously shown in several randomized controlled trials for laparoscopic colectomy [33, 34].

The potential benefits of single-port-access surgery remain to be proved but potentially include less morbidity and postoperative pain, shorter hospital stay, and faster recovery, in addition to the cosmetic advantage. The decrease in abdominal wall trauma could be especially useful for cirrhotic patients, provided the incision is made through the rectus abdominis muscle or in the supraumbilical position to avoid bleeding from large umbilical veins and to allow a secure closure.

Single-port-access surgery remains a demanding procedure. Using the GelPort approach, however, makes it possible to triangulate even with standard instruments, to ensure immediate control of any major bleed site if necessary, and to use large instruments such as standard ultrasound probes, LigaSure devices, and staplers. In the future, wider development of specific curved instruments, including ligation devices, will further improve the ease and safety of these procedures.

Hepatectomy of the left liver is ideal for a single-port-access approach because the suspensory ligament of the liver helps the surgeon and his or her assistant with the surgical-site exposure. Moreover, the line of intended liver parenchyma division is in the same in-line axis of the port sites and instrumentation that help to avoid conflict between the operator and the camera holder. Nevertheless, when necessary, the surgeon can easily convert the single-port-access approach into a standard multiport laparoscopic procedure, making this technique as safe as conventional laparoscopic surgery.

One worry about the single-port-access approach has been the longer surgical time, which should rapidly improve with growing experience. As an example, in colorectal surgery, the first reports of single-port-access surgery concerned right hemicolectomy for benign disease [22], but currently, oncologic [19] and complex procedures such as total proctocolectomy with ileal pouch anal anastomosis [35] are performed. To minimize blood loss and to facilitate the procedure, the Pringle maneuver was used in all cases, with control of the porta hepatis using a disposable device just as would be used for open surgery.

In the third case, the hepatectomy was performed by microwave precoagulation. Intraoperatively, before parenchymal transection, a zone of heat coagulative necrosis along the line of intended liver parenchyma division was performed. After this, the parenchymal transection was performed using simple laparoscopic scissors to ensure a bloodless procedure. This technical refinement may allow larger anatomic resections in the future, such as left lateral sectorectomy. However, all these procedures are similar to techniques we used for open hepatectomy, emphasizing the ease with which standard techniques can be adopted to a laparoscopic approach for improvement of patient outcome.

This preliminary experience with liver resection via a single-port access suggests its technical feasibility and safety in terms of intra- and postoperative results. Nevertheless, this remains a challenging procedure, requiring both hepatobiliary and laparoscopic experience. Additional experiences are mandatory to assess the interest and safety of this emerging technique.

Acknowledgments We thank Terry Helms for the figure and Meryl Greenblatt for her help in the preparation of the manuscript.

Disclosure Yuman Fong is scientific advisor for Covidien and Ethicon. Sébastien Gaujoux, T. Peter Kingham, William R. Jarnagin, Michael I. D'Angelica, and Peter J. Allen have no conflicts of interest or financial ties to disclose.

References

1. Gagner M, Rheault M, Dubuc J (1992) Laparoscopic partial hepatectomy for liver tumor. Surg Endosc 6:99 (Abstract)
2. Azagra JS, Goergen M, Gilbart E, Jacobs D (1996) Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects. Surg Endosc 10:758–761
3. Kaneko H, Takagi S, Shiba T (1996) Laparoscopic partial hepatectomy and left lateral segmentectomy: technique and results of a clinical series. Surgery 120:468–475
4. Fong Y, Jarnagin W, Conlon KC, DeMatteo R, Dougherty E, Blumgart LH (2000) Hand-assisted laparoscopic liver resection: lessons from an initial experience. Arch Surg 135:854–859
5. Cherqui D, Husson E, Hammoud R, Malassagne B, Stephan F, Bensaid S et al (2000) Laparoscopic liver resections: a feasibility study in 30 patients. Ann Surg 232:753–762
6. Ito K, Ito H, Are C, Allen PJ, Fong Y, DeMatteo RP et al (2009) Laparoscopic versus open liver resection: a matched-pair case control study. J Gastrointest Surg 13:2276–2283
7. Topal B, Fieuws S, Aerts R, Vandeweyer H, Penninckx F (2008) Laparoscopic versus open liver resection of hepatic neoplasms: comparative analysis of short-term results. Surg Endosc 22:2208–2213
8. Buell JF, Thomas MT, Rudich S, Marvin M, Nagubandi R, Ravindra KV et al (2008) Experience with more than 500 minimally invasive hepatic procedures. Ann Surg 248:475–486
9. Nguyen KT, Laurent A, Dagher I, Geller DA, Steel J, Thomas MT et al (2009) Minimally invasive liver resection for metastatic colorectal cancer: a multi-institutional, international report of safety, feasibility, and early outcomes. Ann Surg 250:842–848

10. Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, Dagher I et al (2009) The international position on laparoscopic liver surgery: the Louisville Statement, 2008. Ann Surg 250:825–830
11. Dagher I, O'Rourke N, Geller DA, Cherqui D, Belli G, Gamblin TC et al (2009) Laparoscopic major hepatectomy: an evolution in standard of care. Ann Surg 250:856–860
12. Nguyen NT, Reavis KM, Hinojosa MW, Smith BR, Stamos MJ (2009) A single-port technique for laparoscopic extended stapled appendectomy. Surg Innov 16:78–81
13. Nguyen NT, Reavis KM, Hinojosa MW, Smith BR, Wilson SE (2009) Laparoscopic transumbilical cholecystectomy without visible abdominal scars. J Gastrointest Surg 13:1125–1128
14. Bucher P, Pugin F, Morel P (2009) Transumbilical single-incision laparoscopic intracorporeal anastomosis for gastrojejunostomy: case report. Surg Endosc 23:1667–1670
15. Barbaros U, Dinccag A (2009) Single-incision laparoscopic splenectomy: the first two cases. J Gastrointest Surg 13:1520–1523
16. Nguyen NT, Reavis KM, Hinojosa MW, Smith BR, Wilson SE (2009) Laparoscopic transumbilical sleeve gastrectomy without visible abdominal scars. Surg Obes Relat Dis 5:275–277
17. Reavis KM, Hinojosa MW, Smith BR, Nguyen NT (2008) Single-laparoscopic incision transabdominal surgery sleeve gastrectomy. Obes Surg 18:1492–1494
18. Teixeira J, McGill K, Binenbaum S, Forrester G (2009) Laparoscopic single-site surgery for placement of an adjustable gastric band: initial experience. Surg Endosc 23:1409–1414
19. Bucher P, Pugin F, Morel P (2008) Single-port-access laparoscopic right hemicolectomy. Int J Colorectal Dis 23:1013–1016
20. Bucher P, Pugin F, Morel P (2010) Transumbilical single-incision laparoscopic sigmoidectomy for benign disease. Colorectal Dis 12:61–65
21. Ostrowitz MB, Eschete D, Zemon H, DeNoto G (2009) Robotic-assisted single-incision right colectomy: early experience. Int J Med Robot 5:465–470
22. Remzi FH, Kirat HT, Kaouk JH, Geisler DP (2008) Single-port laparoscopy in colorectal surgery. Colorectal Dis 10:823–826
23. Merchant AM, Lin E (2009) Single-incision laparoscopic right hemicolectomy for a colon mass. Dis Colon Rectum 52: 1021–1024
24. Leroy J, Cahill RA, Asakuma M, Dallemagne B, Marescaux J (2009) Single-access laparoscopic sigmoidectomy as definitive surgical management of prior diverticulitis in a human patient. Arch Surg 144:173–179
25. Rieger NA, Lam FF (2009) Single-incision laparoscopically assisted colectomy using standard laparoscopic instrumentation. Surg Endosc 24:888–890
26. Bucher P, Pugin F, Morel P (2009) Single-port access laparoscopic radical left colectomy in humans. Dis Colon Rectum 52:1797–1801
27. Weber JC, Navarra G, Jiao LR, Nicholls JP, Jensen SL, Habib NA (2002) New technique for liver resection using heat coagulative necrosis. Ann Surg 236:560–563
28. Piskun G, Rajpal S (1999) Transumbilical laparoscopic cholecystectomy utilizes no incisions outside the umbilicus. J Laparoendosc Adv Surg Tech A 9:361–364
29. Filipovic-Cugura J, Kirac I, Kulis T, Jankovic J, Bekavac-Beslin M (2009) Single-incision laparoscopic surgery (SILS) for totally extraperitoneal (TEP) inguinal hernia repair: first case. Surg Endosc 23:920–921
30. Ponsky TA, DiLuciano J, Chwals W, Parry R, Boulanger S (2009) Early experience with single-port laparoscopic surgery in children. J Laparoendosc Adv Surg Tech A 19:551–553
31. Fader AN, Escobar PF (2009) Laparoendoscopic single-site surgery (LESS) in gynecologic oncology: technique and initial report. Gynecol Oncol 114:157–161
32. Raman JD, Cadeddu JA, Rao P, Rane A (2008) Single-incision laparoscopic surgery: initial urological experience and comparison with natural-orifice transluminal endoscopic surgery. BJU Int 101:1493–1496
33. Larson DW, Marcello PW, Larach SW, Wexner SD, Park A, Marks J et al (2008) Surgeon volume does not predict outcomes in the setting of technical credentialing: results from a randomized trial in colon cancer. Ann Surg 248:746–750
34. Fleshman J, Sargent DJ, Green E, Anvari M, Stryker SJ, Beart RW Jr et al (2007) Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST Study Group trial. Ann Surg 246:655–662
35. Geisler DP, Condon ET, Remzi FH (2009) Single-incision laparoscopic total proctocolectomy with ileopouch anal anastomosis. Colorectal Dis 9:941–943