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ORIGINAL ARTICLE

Surgical complications of laparoendoscopic single-site donor nephrectomy: a retrospective study

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SUMMARY

The single-port approach has been associated with an unacceptably high rate of umbilical port hernias in large series of patients undergoing single-port cholecystectomy and colectomy and with additional surgical risks thought secondary to technical and ergonomic limitations. A retrospective review of 378 consecutive laparoendoscopic single-site(LESS) donor nephrectomies performed between 04/15/2009 and 04/09/2014 was conducted. Twelve patients (3%) developed an umbilical hernia. Eleven (92%) were female and eight (73%) of these patients had a prior pregnancy. Hernias were reported 13.5 ± 6.9 months after donation, and the mean size was 5.1 ± 3.7 cm. Seven additional cases (1.9%) required a return to the operating room for internal hernia (2), evisceration (1), bleeding (1), enterotomy (1), and wound infection (2). The original incision was utilized for reexploration. One patient required emergent conversion to an open procedure for bleeding during the initial donation. There were no mortalities. Recipient patient and graft survival were 99% and 99% at 1 year, respectively. Although reports associated with earlier experiences with single-site procedures suggested an unacceptably high rate of hernias at the surgical site, this does not seem to be the case at our center. This technique is a reliable surgical technique for left donor nephrectomy at this institution.

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Introduction

Since its advent in 1995 [1,2], laparoscopic donor nephrectomy has become the standard of care for living renal donation. At most centers, when compared to the traditional open technique, this procedure resulted in decreased donor morbidity and hospital length of stay, while still achieving equivalent allograft outcomes [3,4]. Ultimately, these benefits were found to lead to increased organ donation rates at our center [5]. While maintaining the paramount focus on maximal donor safety, laparoscopic donor nephrectomy has developed into a reliable, reproducible, minimally invasive approach leading to an expedient donor recovery.

In 2009, our center adopted the laparoendoscopic single-site (LESS) approach as our standard of care for donor nephrectomy. This technique limits the number of trocar sites to a single transumbilical incision that is camouflaged within the umbilical skin fold. We have previously reported that single-port donor nephrectomies

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provided improved patient satisfaction and equivalent outcomes when compared with the preceding cohorts of standard multiport laparoscopic nephrectomies [6].

Due to the technical challenges associated with single-site surgery, relatively few centers have adopted this approach. As such, there is a paucity of reports regarding the surgical complications inherent to the single-site approach for donor nephrectomy [6–9]. Although we did not note this in our earlier experience, the single-port approach was associated with an unacceptably high rate of umbilical port hernias in large series of patients undergoing single-port cholecystectomy [10]. Here, we report our experience with nearly 400 consecutive single-site donor nephrectomies, and the associated surgical complications we have noted with this approach.

Patients and methods

Patients

Potential donors were evaluated by our multidisciplinary living donor kidney selection committee for donor eligibility and safety. Patients with significant medical comorbidities, complicated hypertension (uncontrolled on a single antihypertensive agent), diabetes, coronary artery disease, or a BMI greater than 35 were excluded. All donors underwent electrocardiogram, chest radiograph, and computed tomography angiogram. A retrospective review of our institution's prospectively collected transplant database was performed to identify and collect data from all donors undergoing LESS donor nephrectomy at our center. This was performed after receiving institutional review board approval (HP-00044585). This study was in compliance with guidelines set forth in the 2000 Declaration of Helsinki and the Declaration of Istanbul 2008.

Laparoscopic single-port nephrectomy technique

Our surgical approach has been reported previously [6]. Briefly, patients were positioned in a lateral decubitus position. Left nephrectomy was performed in the vast majority of cases (97 percent). In cases of right nephrectomy, the GelPOINT (Applied Medical, Rancho Santa Margarita, CA, USA) was used by all surgeons to facilitate placement of a fourth transumbilical port for liver retraction. In left nephrectomy, a 2-3 cm (single-incision laparoscopic surgery (SILS) port, Covidien; Mansfield, MA, USA) or 4-5 cm GelPOINT(Applied Medical, Rancho Santa Margarita, CA) vertical incision was centered on the umbilicus. The abdomen was insufflated to 15 mmHg, and a cursory laparoscopy was performed. The colon was mobilized using harmonic scalpel (Ethicon, San Angelo, TX, USA) dissection and gentle blunt traction from the splenic flexure to the pelvic brim. Harmonic scalpel utilization tended to minimize bleeding during dissection. During renal mobilization, gentle blunt dissection was often a necessity. When bleeding was encountered, it was most commonly controlled with direct pressure and placement of Surgicel (Ethicon; TX, USA). In cases where small bleeding vessels were directly visualized, these were controlled with metal clips. While direct suture ligature of bleeding vessels is possible using the single-port technique, we found this to rarely be necessary.

The ureter-gonadal vein complex was isolated at the level of the iliac vessels, and dissected to the renal hilum, exposing the junction of the gonadal vein and the left renal vein. A laparoscopic bowel grasper was used to elevate the lower pole, facilitating exposure of the lower border of the left renal vein and any lumbar veins. Lumbar veins were typically divided with the harmonic scalpel, although larger branches were occasionally divided with metal clips (Endo Clip 5 mm clip device, Covidien) or stapling. Lateral traction was then placed on the upper pole of the kidney, and a plane between the adrenal gland and the kidney developed with the harmonic scalpel. The posterior attachments of the kidney were then freed, and the renal artery dissected circumferentially using both anterior and posterior approaches. The renal artery was typically dissected to within 5 mm of its origin from the aorta, and the renal vein dissected beyond the aorta. The adrenal vein was divided on a case-by-case basis, depending on the length and mobility of the donor renal vein. Most commonly, the adrenal vein was divided at the completion of the nephrectomy during division of the renal vein. This was done by applying the vascular stapler to the renal vein at a slightly oblique angle. In cases where it was necessary to maximize renal vein length, the adrenal vein was circumferentially dissected, and then divided with the harmonic scalpel between metal clips.

When the recipient team was ready to receive the kidney, a 15 mm port was inserted through one of the 5 mm ports in the single-port device, and the ureter-gonadal vein complex divided at the pelvic brim with an Endo GIA vascular load stapling device (Covidien; Mansfield, MA). The vein and artery were then stapled sequentially. Following stapling of the vasculature, staple lines were rapidly inspected for hemostasis. A 15 mm Endo Catch (Covidien; Mansfield, MA) bag was inserted

through the port that was used for stapler insertion. The donor kidney was then placed into the specimen pouch under direct vision. The cylindrical tube and handle of the Endo Catch device were then removed, with care to control the suture loop that encircles the specimen pouch. The port was then removed. In cases utilizing the SILS port, the fascial and skin incisions were enlarged 1-3 cm prior to extraction of the specimen pouch and kidney. The fascia was then partly closed to allow for port replacement and abdominal re-insufflation. Mesocolonic defects, when identified, were closed with either metal clips or interrupted sutures tied intracorporeally. Our standard fascial closure was with interrupted #1 polydioxanone (PDS) sutures (Ethicon; TX, USA) placed by an attending surgeon.

As we gained experience with the procedure, two surgeons preferentially utilized the SILS port (RB, JL) and three preferred the GelPOINT (DL, MP, SN). Operative equipment varied depending on the access port utilized. In the case of the GelPOINT, three 5 mm ports and one 12 mm port (to accommodate a standard 10 mm 30 degree angled camera) were inserted through the gel. The SILS port device has three 5 mm ports, and a 5 mm LTF-VP deflectable tip video laparoscope (Olympus, Center Valley, PA, USA) was used.

Five percent of patients required additional port placement due to exposure or safety concerns. In the vast majority of these cases, one (approximately 65%) or two (approximately 30%) additional ports were placed.

Instruments

Occasionally due to patient habitus, a long bariatric harmonic scalpel was required to mobilize the upper pole of the kidney. Bariatric length suction irrigator devices were routinely used. Standard and bariatric length Maryland dissectors were used in most cases. Articulating dissection instruments (Covidien; Mansfield, MA) were rarely used at surgeons' discretion.

Medications

All donors received standard antibiotic prophylaxis per hospital routine, typically one gram of cefazolin (Ancef, GlaxoSmithKline, London, UK) intravenously. Patients did not routinely receive heparin. Local anesthetic was injected at the completion of fascial closure. Since 2013, liposomal bupivacaine (Exparel, Pacira, Parsippany, NJ, USA) has been utilized as a long-acting local anesthetic.

Follow-up

Patients are advised to avoid heavy lifting for 8 weeks. All patients were contacted and asked about the presence of hernia, development of any new medical problems, and/or the occurrence of surgery or hospitalization at 6, 12, and 24 months following donation.

Data analysis

We compiled surgical results and follow-up data from 378 consecutive LESS renal donors using our secure transplant patient database. We collected demographic factors such as age, body mass index, gender, and laterality of donation. Variables included rates of return to the operating room, blood transfusion, conversion to open, and hernia formation, and time to cross-clamp.

Statistical analysis

Patient characteristics were presented for the full cohort and according to hernia distribution using proportions and frequencies for categorical variables, and means with standard deviations for continuous variables. Medians with interquartile range were reported for skewed distributions. Independent group *t*-tests and chi-square tests were used for bivariate comparisons. Kaplan–Meier methods were used to present the probability of hernia formation in a time to event analysis. The log-rank test was used to compare survival distributions between the two groups of donor nephrectomy by era. All statistical analyses were conducted using Stata Statistical Software (Release11.2. College Station, Texas, USA: StataCorp LP).

Results

From 04/15/2009 to 04/09/2014, 378 LESS donor nephrectomies were performed.

Demographics

Table 1 summarizes baseline demographic and operative characteristics. The majority of donors were female ($n = 257$, 68%) and had their left kidney removed ($n = 365$, 97%). The mean age at donation was 44 ± 12.6, and the mean BMI at donation was 27 ± 4.5.

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Table 1. Baseline characteristics.

	N	%
Female gender	257	68
Left kidney removed	365	97
Hernia	12	3

	Range	Mean (SD) or Median (IQR)*
Age (years)	19–73	44.0 (12.6)
BMI (kg/m²)	18–44	27.5 (4.5)
Estimated blood loss (mls)	0–1 000	50.0 (30.0–100.0)*
Time to cross-clamp (h)	1–5	2.7 (0.7)
Time to hernia (months)	7–20	12.4 (4.5)

Based on 378 cases.

*Median with interquartile range.

Postoperative hernia

The most common surgical complication was umbilical hernia, the timing of which is shown in Fig. 1. Twelve patients developed an umbilical hernia (3%) following donation. Eleven were female (92%), however, this did not reach statistical significance. Prior pregnancy was noted in eight of 11 (73%) of these patients. Six donors who ultimately developed hernias had undergone prior transumbilical surgical procedures. All of these donors were female, and five of six had had prior pregnancies. Two of these donors had had an umbilical hernia noted at the time of donation. Other operative variables that would be expected to correlate with technical complexity of the surgery (cross-clamp time, estimated blood loss, BMI, age, and laterality of donation) were not associated with subsequent hernia formation. One patient who developed hernia had required a single additional 5 mm port due to poor exposure from fatty, adherent perinephric fat (BMI 27). Hernia formation did not correlate with the single-port device (GelPOINT $n = 5$, SILS port $n = 7$) or surgeon of record (Table 2).

Hernias were reported 12.4 ± 4.5 months after donation, and the mean size was 5.1 ± 3.7 cm. All hernias occurred at the original port site incision. The majority (8) was primarily repaired with permanent interrupted sutures, but mesh was utilized in four cases. Flaps and relaxing incisions were utilized in two hernias that were repaired primarily. There were no cases of hernia recurrence.

There was no detectable era effect in comparing the rate of hernia formation in the first and second halves of the study period. (Fig. 2)

Additional surgical complications

Return to the operating room ($n = 7$)

Seven cases (1.9%) required a return to the operating room. Two patients required exploration for internal hernia secondary to a mesenteric defect in the left mesocolon. One patient developed a wound infection resulting in evisceration requiring emergent exploration. One patient developed a bowel obstruction following a repair to an enterotomy during the initial donation surgery and required exploration and bowel

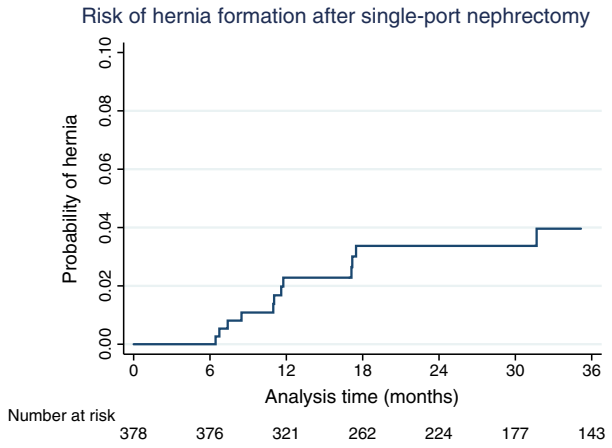

Figure 1 Risk of hernia formation after single-port donor nephrectomy. Most hernias were detected within 18 months of donation. There were no hernias reported within the first 6 months, and the rate of development of hernia plateaued at 2 years.

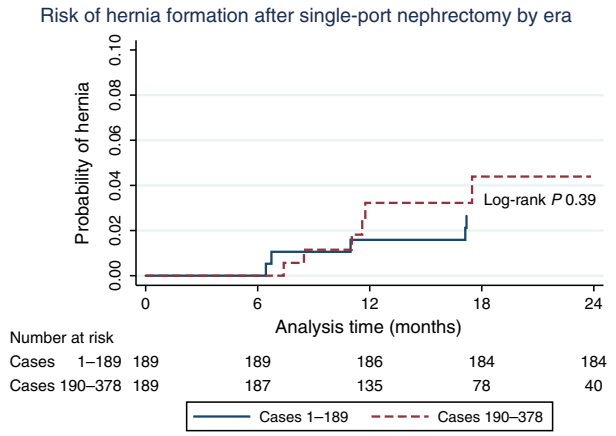

Figure 2 Risk of hernia formation after single-port donor nephrectomy by era. The rate of hernia formation was not different between the first half of our institutional experience and the second half. There was not a demonstrable "learning curve" in regards to postoperative hernia formation.

resection. One patient was explored for bleeding and hematoma evacuation following right nephrectomy and was found to have bleeding from the adrenal gland and gonadal vein. Two additional patients had persistent wound infections that did not respond to antibiotics and outpatient wound care. The original incision was utilized for reexploration in all cases, but the fascial incision was enlarged in one of the internal hernia cases. All patients recovered without further sequelae (Table 3).

Conversion to open ($n = 1$)

One case required emergent conversion to an open technique via a midline incision for an arterial injury sustained during stapling. The renal artery stump was oversewn at the level of the aorta. This patient made an uneventful recovery.

Interventional drain placement ($n = 1$)

One patient developed an intra-abdominal abscess of unclear etiology without radiographic evidence of enteric perforation. This was treated conservatively with antibiotics and drainage by interventional radiology. This patient made an uneventful recovery.

Blood transfusion ($n = 3$)

The patient who underwent emergent conversion to open nephrectomy and the patient who was explored for a retroperitoneal hematoma required blood transfusions. One additional patient developed a significant hematoma in the nephrectomy bed and required a two-unit blood transfusion.

Recipient outcomes

There were no cases of kidney fracture or significant damage from the dissection or extraction from the port site. Patient and graft survival were 99% and 99% at 1 year, respectively. During the study period, four patients died with a functioning graft within the first year. Causes of death included sudden cardiac arrest, malignancy (2), and infection. One additional graft was lost during the first year from renal artery thrombosis in the immediate perioperative period.

Discussion

Laparoendoscopic single-site surgery has been the standard of care at our center for the past 5 years. In our previous report, it was documented that there were potential patient benefits when adopting this minimally invasive method. However, other centers have noted a potentially unacceptably high rate of hernia formation following introduction of a transumbilical LESS approach for other general surgical cases [10,11]. To further explore the potential surgical complications of the LESS approach for donor nephrectomy, we reviewed our total experience of nearly four hundred patients over 5 years.

As expected, we found that the most common surgical complication with this approach was the development of an umbilical hernia. At our center, roughly 3% of donors later developed a hernia, and we include this disclosure as part of the informed consent process. This rate remained constant between the first and second "eras" of our experience, suggesting that the relatively steep learning curve that we and others have reported associated with this technique does not affect the hernia

Table 2. Distribution of hernia among covariates.

	Hernia*		
	N (%), Mean (SD)† or Median (IQR) ‡		*P* value
	Yes ($n = 12$)	No ($n = 366$)	
Female gender	11 (92)	246 (67)	0.07
Left kidney removed	12 (100)	353 (96)	0.51
Age (years)	45.5 (10.9)†	44.0 (12.6)†	0.66
BMI (kg/m²)	28.4 (4.4)†	27.4 (4.5)†	0.78
Estimated blood loss (mls)	40.0 (30.0–62.5)‡	50.0 (30.0–100.0)‡	0.45
Cross-clamp time (h)	2.4 (0.8)†	2.7 (0.7)†	0.11

*Based on 378 cases.

†Mean and standard deviation.

‡Median with interquartile range.

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Table 3. Indications for reoperation following LESS* donor nephrectomy.

Indication for reoperation (total *n* = 378)	*n* (%)
Port-site hernia	12 (3.1)
Wound infection/debridement	2 (0.5)
Internal hernia	2 (0.5)
Bleeding	1 (0.25)
Evisceration	1 (0.25)
SBO† from enterotomy repair	1 (0.25)

*LESS=laparoendoscopic single-site.

†SBO=small bowel obstruction.

rate. The majority of cases were performed by two attending surgeons, both of whom had significant laparoscopic experience prior to performing donor nephrectomy via a single-port. This hernia rate compares favorably with that reported following single-incision laparoscopic cholecystectomy (8.4% in 119 patients followed for one year) [10] as well as that following single-port transumbilical sigmoid colectomy for diverticular disease (4.9% in 309 patients followed for 6 months) [12]. As the exposure can sometimes be quite challenging given that the fascial incision often undercuts the skin incision, an experienced surgeon performing the closure may contribute to this lower rate of hernia. Furthermore, we would expect that a healthy donor undergoing elective surgery would demonstrate improved wound healing as compared to a patient undergoing single-port general surgery for disease.

Unexpectedly, nearly all of the patients who developed hernias were female. Prior pregnancy seemed to correlate with this finding as well. As six of the twelve patients who developed a hernia at the extraction site had had a prior transumbilical surgery, prior transumbilical procedures may prove to be a risk factor for postoperative hernia formation, particularly in women with prior pregnancy. Although pregnancy is a widely accepted risk factor for the development of umbilical hernia, the role of prior pregnancy on the development of ventral incisional hernia following a subsequent surgical procedure remains poorly characterized. As pregnancy following ventral hernia repair, either primarily or with mesh, has been associated with recurrence [13,14], a relationship between pregnancy and weakening of the abdominal wall fascia may be intuited. Nonetheless, to our knowledge, no definitive relationship has been proven in a large series.

Hernias were able to be repaired through the original incision in all cases and have not recurred to date. Mesh repair was performed in one-third of cases. Although all patients were asked regarding the development of a hernia at the operative site, direct physical examination or imaging studies were not routinely performed, and it is possible that this study underestimates the occurrence of subclinical hernia formation. This is of unclear significance.

Despite increased experience and comfort with renal donation in general and the LESS technique in particular, this remains a technically demanding operation and there exists a small potential for surgical complications consistent with both multiport and hand-assist approaches. Our group was pleased with the relatively low rate of surgical complications overall, and all patients have made a complete recovery to a normal activity level. Our rate of significant complications is comparable to that reported by the Northwestern group. In their series of 1200 laparoscopic donor nephrectomies performed over more than ten years, they reported seven major vascular injuries requiring conversion to an open procedure, but only one patient requiring reexploration for bowel obstruction, one patient requiring paracentesis, and one patient requiring blood transfusion in the postoperative period [15]. They did, however, report splenic capsular tears (3), a diaphragmatic injury (1), bowel serosal injuries (3), and a renovascular injury (1) that were recognized and addressed at the initial operation. Perhaps this is reflective of the wider visual field and exposure that can be provided by the multiport approach, as our group had a greater rate of return to the operating room postoperatively, but a lower rate of renovascular injuries.

The Minnesota group reported a 4% incisional hernia rate in their series of more than 1 000 hand-assisted laparoscopic donor nephrectomies (with the hand-assist port placed in a 2.5 cm vertical midline incision) [16]. In their more recent multiple port laparoscopic approach in which the donor kidney was extracted via a Pfannenstiel incision, this rate decreased to 2.5%. The Minnesota experience noted a transfusion requirement of 0.3% and a reoperation rate of 1.5% in their multiple port donor nephrectomies. The transfusion rate seen in the Ohio State report (consisting entirely of a hand-assist technique) was likewise quite low (0.27%) [17]. They had a similarly low rate of conversion to an open technique for bleeding (0.27%). The Ohio State group typically used an infraumbilical midline incision for the handport. Hernias were encountered in 1.8% of patients. Six patients required reoperation in the first month (0.4%), but an additional seven patients required exploration for bowel obstruction postdonation (overall nonhernia reoperation rate of 0.87%). A 2013 Dutch

study of 716 living donors relying upon voluntary patient participation in a survey reported a 1.6% incidence of hernia at either a port site ($n = 3$) or the extraction site (Pfannenstiel $n = 2$, McBurney $n = 1$) [18]. Our hernia rate is comparable to that experienced in these large reports, as is our blood transfusion requirement. The return to the operating room rate in our center was 1.9%, a rate which is slightly higher than that seen at other large centers. This may very well be secondary to the increased technical complexity and relatively steep learning curve associated with the single-port technique.

As surgeons continue to be challenged with the increasing BMI of all patients, including donors, the single-port technique will continue to evolve. Although we limited patients to a BMI<30 in our early experience, we have permitted a BMI≤35 for several years. Challenges can typically be overcome utilizing the additional port possible with the GelPOINT device, or, when absolutely necessary, additional port placement.

Although our earlier work supported improved cosmesis and patient satisfaction with the single-port technique compared to historic multiport control patients, we did not repeat this aspect of the study with the present cohort. As the single-port technique has been our standard approach for donor nephrectomy since 2009, we did not feel that we had a valid comparison group of multiport patients in the present era of laparoscopy.

It is the practice at our center to only utilize the right kidney when there is a donor-related safety concern, that is, a large right-sided cyst with a normal left kidney, or a single right-sided kidney stone in a patient without left-sided kidney stones and without a propensity for nephrolithiasis. In addition to surgeon preference, our single-port technique for right nephrectomy requires a dedicated port for liver retraction. This is not possible using the SILS port as there are only three ports (camera, two operative ports). We therefore utilize the GelPOINT for right donor nephrectomies as we are able to place four ports (camera, liver retractor, two operative ports).

Techniques associated with multiport laparoscopy are broadly applicable to the single-port technique, although, due to hand positioning, these techniques tend to be a bit awkward. Often, a process of trial and error is required to optimize exposure of the target anatomy. We have found altering bed position (both degree of Trendelenburg/reverse Trendelenburg and leftward/rightward rotation), utilizing different length instruments in each operative hand (standard versus bariatric length), and switching instruments between the left and right port to be critical components of success in the single-port approach.

After analyzing the outcomes of 378 patients, we have found that LESS donor nephrectomy has a low rate of surgical risks in an experienced center. Although original reports associated with earlier experiences with single-site procedures suggested an unacceptably high rate of hernias at the surgical site, this does not seem to be the case with LESS donor nephrectomy at our center. We have not noted an increased rate of hernia formation with increased length of follow-up. As direct physical examination and/or imaging of the surgical site were not performed in all donors, this hernia rate may ultimately underestimate the degree of hernia risk. Nonetheless, our experience suggests this technique is a reliable surgical technique for left donor nephrectomy at this institution.

Author Contributions

JCL: designed study, performed research, collected data, analyzed data, and wrote paper. JMP: performed research, collected data, and analyzed data. NAC: analyzed data and wrote paper. DBL: reviewed and edited manuscript. SVN: reviewed and edited manuscript. JSB: reviewed and edited manuscript. JAC: collected data, reviewed and edited manuscript. MSP: reviewed and edited manuscript. RNB: designed study, analyzed data, and reviewed and edited manuscript.

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Conflict of interests

The authors have no conflict of interests to disclose.

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