INTRODUCTION
Flank hernias occurring after blunt abdominal trauma are rare. Approximately 500 cases have been reported in the literature [1–18]. In 2009, the European Hernia Society divided lateral hernia into four zones: L1 (subcostal), L2 (flank), L3 (iliac), and L4 (lumbar) [19]. When the hernia is located lateral to the rectal sheath in the area 3 cm above and below the umbilicus, it is defined as flank hernia [19], which is further divided into primary (spontaneous) and secondary (trauma or surgery), with an incidence of 55% for primary and 25% for secondary flank hernia [20].

Traumatic flank hernia repair has been reported only in case series; thus, surgical techniques or long-term outcomes have not been established. Kearney et al. [6] reported that primary repair of traumatic flank hernia using mesh strips provides high tension directly to the hernia defect site and has a low recurrence rate due to force distribution at the suture site. In addition, compared to conventional hernia repair, the range of tissue dissection for repair using mesh strips is not wide, so the risk of damage to surrounding structures is low [6]. Moreover, mesh strip technique can be performed easily and quickly.

In this article, we report a case of a male patient who presented with traumatic flank hernia 3 years postinjury, which was successfully repaired using mesh strips. This is the first reported case of traumatic flank hernia repair using the mesh strip technique in Asia.

This study was approved by the Institutional Review Board of Seoul National University Hospital (No. 2201-130-1294). Written informed consent was obtained from the patient for publication of this case report and accompanying images.
CASE REPORT

A male patient with a history of intrahepatic duct stone surgery was transported to a regional trauma center after he collided with a 15-t truck while driving. His mental status was Glasgow Coma Scale 15, and he complained of severe abdominal pain. The patient was afebrile with a blood pressure of 70/40 mmHg, pulse rate of 68/min, and respiratory rate of 26/min at arrival. Focused assessment of sonography for trauma revealed a large amount of intraabdominal fluid. Shortly, the patient developed severe hypotension, which was unresponsive to resuscitation. Zone 1 resuscitative endovascular balloon occlusion of the aorta was performed, and emergency laparotomy was decided.

A large amount of hematoma due to massive bleeding from the mesenteric avulsion site and transected vessels was observed after crash laparotomy. Bleeders were controlled, and infarcted small bowel (160 cm length) due to mesenteric avulsion (30 cm length, two sites) was resected. Perforated sigmoid colon was also transected. After 2 days, small bowel anastomosis, S-colon anastomosis, and transverse colostomy were performed during second-look laparotomy.

Other accompanying injuries (left humerus fracture, multiple rib and sternum fractures, both feet fractures, and multiple transverse spine fractures) were also treated. Two months later, colostomy repair was performed, and the patient was discharged 4 months after trauma.

Three years after injury, the patient newly developed left flank bulging and discomfort (Fig. 1). Computed tomography revealed abdominal wall defect and bowel herniation sized 5.6 × 11.6 cm above the iliac crest without signs of bowel incarceration (Fig. 2). Repair of traumatic flank hernia with mesh strip suture was planned.

The patient was placed in a right lateral decubitus position. A beanbag was placed under the patient, and negative pressure was applied to fix the posture (Fig. 3). The bed was bent to extend the space between the iliac crest and the costal margin. The incision was made in the midportion of the abdominal wall defect. The skin and subcutaneous tissue were dissected until the external oblique muscle was identified. The transversus abdominis muscle edge of the hernia defect was identified to complete the exposure of the defect. After confirming that the peritoneum was intact, monofilament polypropylene mesh (Bard Davol, Warwick, RI, USA) was cut into strips with a width of 2 cm. The end of each mesh was triangulated for easy pull-through. The transversus abdominis muscle was pierced with a sharp hemostat approximately 2 to 3 cm from the newly debrided edge of the transverse.

Fig. 1. Preoperative (A) anteroposterior and (B) lateral view of a 62-year-old male patient with a traumatic flank hernia (black circles on the patient body indicate flank bulging).
verse abdominis muscle. The mesh strip was then pulled through the muscle and tied like a suture after making the operating table flat. Eight mesh strips were applied with even distance (Figs. 4, 5). After placing the Jackson-Pratt drain over the repaired transversus abdominis muscle, the internal and external oblique muscles were repaired with 1-0 polydioxanone suture. Another Jackson-Pratt drain was placed over the external oblique muscle, and the subcutaneous tissue and skin were closed with 2-0 nylon.

No evidence of fever and surgical site infection was noted postoperatively. On the 8th postoperative day, the Jackson-Pratt drain was drained to less than 10 mL daily and removed, and the patient was discharged. Computed tomography taken 4 months postoperatively confirmed that the surgical site was intact without recurrence (Fig. 6). No recurrence was observed 12 months postoperatively (Fig. 7). The patient confirmed of having no surgical site discomfort, pain, or foreign body sensation while performing daily activities.

DISCUSSION

Traumatic flank hernia is a rare hernia, and surgical approach is difficult due to the surrounding bony structures and major neurovascular structures. Conventional methods of flank hernia repair include open, laparoscopic, and robotic approaches or a combination of these approaches. Regarding the repair technique, primary repair or planar mesh reinforcement is usually performed.

It is recommended that sufficient flap dissection be achieved as wide mesh overlap is imperative. The planar mesh should be covered 5 to 10 cm wider than the size of the hernia defect in both open and laparoscopic approach [4,10–13,15]. For mesh repair

Fig. 2. Preoperative abdominal computed tomography of (A) axial and (B) coronal view show a 5.6×11.6-cm sized left abdominal wall defect above the iliac crest.

Fig. 3. Preoperative patient position. (A, B) Right lateral decubitus position of the patient with the iliac crest at the proper flexion point. The operating table was bent for flank extension.
using the traditional open technique, the mesh should be anchored to the surrounding muscles or bony prominence, and there is a risk of bleeding or nerve injury [4,10–12,15].

In the laparoscopic approach, the rate of surgical site infection or recurrence is lower than that in open repair [4]. However, as the laparoscopic approach requires mobilization of the bowel for mesh fixation, there might be a risk of organ injury [4]. Some studies have suggested that the laparoscopic approach to repair flank hernia should be limited to smaller defects [13–15], although data on the mean hernia defect size are limited.

The most important outcome in hernia repair is the recurrence rate. Table 1 summarizes 18 case series regarding lumbar hernia (including flank hernia) repair targeting a total of 526 patients reported in the literature [1–18]. An open approach was performed in 13 studies, a laparoscopic approach in three studies, a combination of both approaches in one study, and a laparoscopic or robotic approach in one study. The overall recurrence rate of this cohort was 6.1% (0%–13.3%). The causes of lumbar (or flank) hernia recurrence included insufficient mesh overlap or fixation and mesh implantation failure due to infection [10,15,18]. Common complications that occur after hernia repair included seroma, hematoma, and infection [2,7,8,12,13,15,16,18]. Others in-
cluded skin dehiscence, necrosis, chronic pain, and postoperative anemia due to underlying disease or bleeding during surgery [3–5,11,12,14]. Among them, chronic pain was reported in 0% to 42% of the cases [4,5,11,12,14]. The definition of chronic pain is not clear; therefore, it might have been difficult to differentiate between chronic and postoperative pain [4]. Some studies did not assess chronic pain, which might be a reason for the wide range of prevalence of chronic pain in the cases [2,6,7,10,13,15,18].

Using the experimental pig model, a study introduced the mesh sutured repair in 2014 and compared it with standard primary suture [21]. That study demonstrated that mesh suture has higher resistance and tensile strength for pull-through than standard primary suture. According to another report on 107 mesh sutured repairs of abdominal wall defects published in 2016 [22], the recurrence rate (early mean follow-up time of 234 days) was < 4%, and the incidence of surgical site occurrence (infection, seroma, hematoma, reoperation, delayed wound healing) was 17%. Another study published in 2020 reported that among four patients with traumatic flank hernia who underwent mesh strip repair [6], there were no complications such as surgical site infec-

Fig. 6. Postoperative computed tomography scan of (A) axial and (B) coronal view after 4 months show an intact hernia repair site without recurrence or complications.

Fig. 7. Images of (A) anterior and (B) lateral view demonstrating intact surgical wound site 6 months postoperatively.
Table 1. Outcomes of lumbar hernia repair

| Study         | Surgical technique | Repair technique | No. of patients | Mean defect size (cm²) | Mean FU (mo) | Recurrence (%) | Complication (%) |
|---------------|--------------------|------------------|-----------------|------------------------|-------------|----------------|------------------|
| Bender et al. [2] | Open               | Varied           | 25              | NC                     | 5.7         | 12.0           | 28.0             |
| Edwards et al. [4] | Laparoscopy        | Mesh             | 27              | 188                    | 3.6         | 0              | 0                |
| Fei et al. [5]  | Open               | Extended sublay, mesh | 18              | NC                     | 26.2        | 0              | 27.8             |
| Fei et al. [5]  | Open               | Routine sublay, mesh | 23              | NC                     | 24.5        | 13.0           | 13.0             |
| Luc et al. [7]  | Open               | Retromuscular, IPOM | 112             | NC                     | 35.0        | 9.8            | 24.1             |
| Patel et al. [10] | Open              | Varied           | 6               | 78.6                   | 15.4        | 11.5           | 49.2             |
| Petersen et al. [11] | Open            | Sublay, mesh     | 4               | NC                     | 33.0        | 0              | 0                |
| Pezeshk et al. [12] | Open              | Varied           | 29              | 94                     | 21.2        | 3.4            | 31.0             |
| Phillips et al. [13] | Open          | Retromuscular, mesh | 16              | 508                    | 16.8        | 0              | 31.0             |
| Purnell et al. [14] | Open          | Varied, mesh     | 31              | NC                     | 27.7        | 9.7            | 6.5              |
| Veyrie et al. [15] | Open            | Retromuscular, mesh | 61              | 56                     | 47.0        | 4.9            | 11.5             |
| Zieren et al. [18] | Open            | Retromuscular, onlay, mesh | 15              | NC                     | 60.0        | 13.3           | 33.0             |
| Muhkerjee et al. [8] | Open           | Mesh             | 8               | 90                     | 12.0        | 20.0           | 10.0             |
| Novitsky et al. [9] | Laparoscopy   | Mesh             | 14              | NC                     | 35.0        | 0              | 0                |
| Amaral et al. [1]  | Combining laparoscopy and open | Laparoscopic IPOM and open onlay, mesh | 16              | NC                     | 37.0        | 12.5           | 6.3              |
| Cavalli et al. [3]  | Open               | Retromuscular, mesh | 22              | 232                    | 44.8        | 4.5            | 9.1              |
| Zhao et al. [17]  | Laparoscopy       | TAPE, mesh       | 19              | NC                     | 20.0        | 0              | 0                |
| Wijerathne et al. [16] | Laparoscopy, robot | Varied, mesh    | 21              | 19.8                   | 14.0        | 0              | 18.2             |
| Kearney et al. [6] | Open               | Mesh strip       | 4               | NC                     | 24.3        | 0              | 0                |

FU, follow-up; NC, not calculated; IPOM, intraperitoneal onlay mesh; TAPE, transabdominal partially extraperitoneal.

aData mean, 8.9±11.7 cm. bA total of 61 lumbar hernia patients (subcostal hernia, 14 patients; flank hernia, 33 patients; iliac hernia, 11 patients; lumbar hernia, 3 patients). cData mean, 11.1 cm. dA total 61 lateral incisional hernia (subcostal hernia, 14 patients; flank hernia, 12 patients; iliac hernia, 35 patients). eData mean, 15±11 cm. fData mean, 6±9 cm. gData mean, 6.4±2.8 cm. hData mean, 5.8±2.1 cm.

traumatic, hematoma, or wound breakdown and no recurrence during the mean period of 24.3 months of follow-up. The authors suggested that targeted placement of the mesh at the repair site using strips of mesh distributes the forces of closure across a larger surface area, helping to reduce the likelihood of pull-through with improved outcomes [6]. In addition, mesh suture creates a magnified foreign body response because of its increased surface area [22]. Persistent foreign body response and associated scar formation would be important for the long-term strength of hernia defect closure [22].

There were two reasons for selecting mesh strips sutured repair for the present case. First, due to the large size of the hernia defect, extensive tissue dissection would have been required for traditional mesh application, which might have increased the risk of postoperative complications. The hernia was located at the L2–L3 boundary according to classification, and it was difficult to secure a sufficient operative field on the inferior border for planar mesh repair. Second, the tension of the surrounding tissue was anticipated to be weak compared to other types of flank hernias. As the patient had very high energy in-car traffic accident, seat-belt might have damaged the fascia and muscles. The injured tissues may have been stretched due to long-standing exposure of intraabdominal pressure and may have progressed to an abdominal wall defect. Since the tension of surrounding tissue was anticipated to be weak, the magnified foreign body response, which is an advantage of the mesh strip suture, would be helpful. Therefore, sutured repair using mesh strips was selected so as to increase the tensile strength of the transversus abdominis muscle with less surrounding tissue dissection.

In conclusion, when it is difficult to secure a sufficient operative field for mesh anchoring in a traumatic flank hernia, a technique of sutured repair with mesh strips may be considered as a treatment option, given that this technique requires less dissection, thereby reducing the risk of injuries and ischemic necrosis of the surrounding tissue, compared to the conventional planar mesh repair. However, this technique has a limitation that it cannot be applied when there is tissue loss or edges of the hernia cannot be approximated. Further studies are warranted to evaluate the safety and efficacy of the mesh strips suture in traumatic flank hernia repair.
NOTES

Ethical statements
This study was approved by the Institutional Review Board of Seoul National University Hospital (No. 2201-130-1294). Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Conflicts of interest
The authors have no conflicts of interest to declare.

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Author contributions
Conceptualization: all authors; Data curation: all authors; Methodology: all authors; Project administration: all authors; Writing–original draft: all authors; Writing–review & editing: all authors.
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