General Thoracic and Cardiovascular Surgery (2019) 67:608–614
https://doi.org/10.1007/s11748-018-01060-9

ORIGINAL ARTICLE

Reoperation for postoperative bleeding following pulmonary resection: a report of a single-center experience

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Received: 9 November 2018 / Accepted: 28 December 2018 / Published online: 17 January 2019

Abstract

Objective The variety and incidence of postoperative complications seem to have changed with recent progress in thoracic surgery. This study attempted to improve our recognition of postoperative bleeding.

Methods Among 1143 patients undergoing pulmonary resection for pulmonary nodules, ten underwent surgical treatment for postoperative bleeding. Clinical and pathologic data were analyzed. Additionally, the relationship between the bleeding point and an increased amount of drained bloody effusion before the second operation was analyzed.

Results The bleeding point was recognized in eight cases: the intercostal artery ($n=4$), the lung ($n=2$), aberrant vessel of the apex of the lung ($n=1$) and the bronchial artery ($n=1$). The bleeding points were unknown in two cases in whom the decision to perform a second operation was delayed. Potential reasons or influential factors for bleeding were stapling complications ($n=4$), low coagulation ability ($n=2$) and intraoperative injury ($n=1$). We experienced two cases in which intercostal arterial bleeding was induced by scratching the thoracic wall or the vertebra with the edge of the reinforced stapling line or the sharp edge of a broken staple at the first operation. We divided patients into three groups based on the interval between operations. Bleeding from the arteries seemed to show a higher rate of bleeding per hour than that from the lung parenchyma.

Conclusion The bleeding points and speculated reasons for bleeding varied among patients. We were able to cure all ten cases. It might be dependent on the rapid decision of reoperation in cases with arterial bleeding was suspected.

Keywords Reoperation · Postoperative bleeding · Pulmonary resection

Introduction

Minimally invasive thoracic surgery is increasingly frequently performed and may lead to a reduction in postoperative pain, shorter hospitalization, and quicker functional and social recovery. However, despite the spread of minimally invasive thoracic surgery, we sometimes encounter cases that require postoperative reoperation. Postoperative bleeding has been considered a main cause of postoperative reoperation. Postoperative bleeding occurred in 2.9% of cases that underwent lobectomy [1]. Recent advances in surgical techniques appear to have reduced the incidence of postoperative bleeding [2–4]; however, such bleeding still sometimes induces a fatal condition. Various causes of postoperative bleeding have been proposed, and some cases also present with rare causes.

To improve our recognition of this condition, we performed a retrospective analysis of patients who underwent reoperation for postoperative bleeding following the first operation of pulmonary resection.

Materials and methods

A retrospective review was conducted for 1143 patients who underwent pulmonary resection for pulmonary nodules, including pneumonectomy ($n=9$), lobectomy ($n=636$), segmentectomy ($n=70$) and wedge resection ($n=428$), at Aichi Medical University Hospital between March 2007 and October 2018. During this time period, ten patients underwent reoperation for postoperative bleeding. Clinical and pathologic data were analyzed in the present study. The criteria for reoperation for postoperative bleeding were a bleeding volume over 1000 ml for 10 h or ≥ 200 ml/h if the bleeding

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volume continued for a few hours. However, reoperation was also allowed in other situations, such as with a huge coagula recognized radiologically even if the criteria were not satisfied. Criteria for intraoperative and postoperative blood transfusion were not established. Anesthesiologists and doctors of our intensive-care unit usually decide on the need for blood transfusion for individual patients based on their blood analysis data.

This study was approved by the Institutional Review Board of Aichi Medical University Hospital. The analyzed values are presented as the mean ± standard deviation (SD).

Results

Clinical data of patients and the first operation (Table 1)

The clinical and pathological data of all ten cases are listed in Table 1. The incidence of reoperation for postoperative bleeding was 0.9% (10/1143). There were eight men and two women, with a median age of 67 years (range 50–79 years). The pathological diagnoses of the pulmonary nodules were lung cancer ($n=9$) and pulmonary metastasis ($n=1$). One patient took warfarin for atrial fibrillation before surgery. It was stopped preoperatively, and substitutive heparin was given intravenously. Thoracotomy was predominantly performed on the right side ($n=7$). The operations performed were lobectomy ($n=5$), segmentectomy ($n=1$) and wedge resection ($n=4$). The mean operation time was 210 ± 55 min. The mean blood loss was 186 ± 338 g. Intrathoracic adhesion was observed in seven cases. Wide and hard adhesion and pleural thickness were observed in a case.

Postoperative bleeding and the second operation (Table 2)

The mean interval between operations was 2321 ± 5631 (min) (20–18,305 min). This large SD can be attributed to re-exploration being performed on postoperative day 13. That case is presented below as case 1. The preoperative condition was stable in all cases except for case 1. The amount of drained bloody effusion was 856 ± 477 ml (200–1700 ml). The bleeding point was recognized in eight cases intraoperatively and was unknown in the other two cases. The bleeding points were the intercostal artery of the thoracotomy ($n=2$) and the different intercostal artery from thoracotomy ($n=2$). In two cases, laceration of the pulmonary stapling line was observed. In one case, an aberrant vessel of the apex of the lung bridging the parietal and visceral pleura was observed at the first operation; this aberrant artery became disconnected, and arterial bleeding was observed. In another case, bleeding was observed from the stump of the bronchial artery. Potential reasons or influential factors for bleeding were stapling complications ($n=4$), low coagulation ability following anticoagulation medication or blood loss by the primary operation ($n=2$), intraoperative injury of the aberrant vessel ($n=1$) and unknown reasons ($n=3$). The mean second operation time was 105 ± 33 min. The mean blood loss was 1443 ± 1626 g. There were no fatal cases or severe complications following bleeding. The mean duration of hospital stay following the second

Table 1 Clinical data of patients and the first operation

Factors	All cases ($n=10$)
Age	66 ± 11 years (50–79 years)
Gender	Male ($n=8$) Female ($n=2$)
BMI	20.7 ± 3.2 kg/m^2
Brinkman index	923 ± 859 (0–2500)
Clinical diagnosis of the lung nodule	Lung cancer ($n=9$) Pulmonary metastasis ($n=1$)
Pathological diagnosis of the lung nodule	Lung cancer ($n=8$) Pulmonary metastasis ($n=1$) Benign lesion ($n=1$)
Underlying disease	Atrial fibrillation with warfarin ($n=1$)
Lung resection	Lobectomy ($n=5$) Segmentectomy ($n=1$) Wedge resection ($n=4$)
Intrathoracic adhesion	None ($n=3$) Partial ($n=3$) Wide and soft ($n=3$) Wide and hard ($n=1$)
Duration of the first operation	210 ± 55 min (113–269 min)
Intraoperative blood loss of the first operation	186 ± 338 g (30–1139 g)

Table 2 Postoperative bleeding and the second operation

Interval between operations	2321 ± 5631 (min) (20–18305 min) Group 1 (red bars in Fig. 1): 24–114 min Group 2 (orange bars in Fig. 1): 472–1230 min Group 3 (blue bars in Fig. 1): 18,305 min
Amount of drained bloody effusion between operations ($n=9$[a])	856 ± 477 ml (200–1700 ml)
Bleeding site	Intercostal artery ($n=4$) Lung ($n=2$) Aberrant vessel of the apex of the lung ($n=1$) Bronchial artery ($n=1$) Unknown ($n=2$)
Speculated reasons or influenced factors of the bleeding	Stapling complication ($n=4$) Low coagulation ability ($n=2$) Intraoperative injury of the aberrant vessel ($n=1$) Unknown ($n=3$)
Hospital stay following the second operation	11 ± 8 days (4–25 days)
Observation period	1140 ± 1092 days
Prognosis	Alive ($n=6$) Dead ($n=4$) (Lung cancer: $n=1$) (Other causes: $n=3$)

[a]Chest tube drainage was not performed before the emergency operation in a case (case 1)

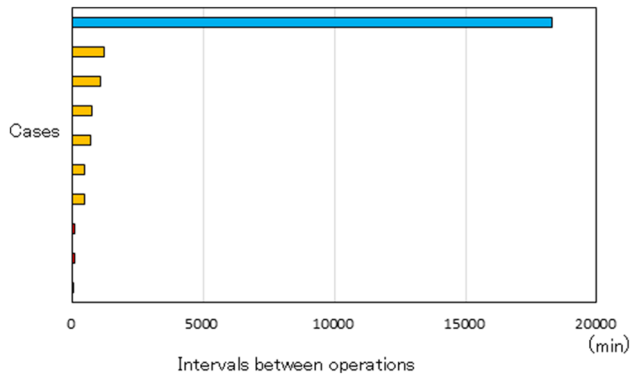

Fig. 1 Intervals between operations. Group 1 (red bar): re-exploration was decided upon rapidly. Group 2 (orange bar): re-exploration was decided upon within a day. Group 3 (blue bar): bleeding occurred a long time after the first operation

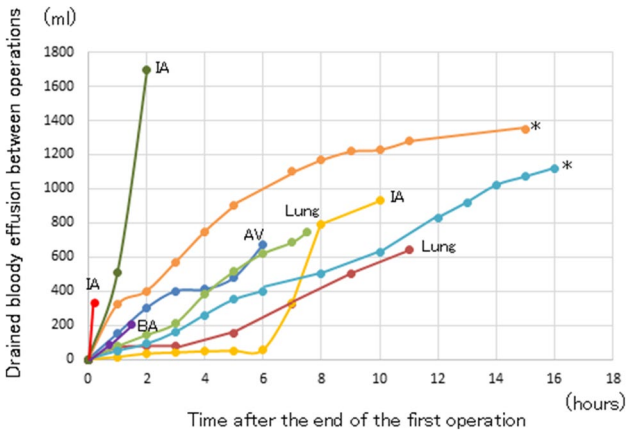

Fig. 2 Relationship between the bleeding point and an increased amount of drained bloody effusion per hour. *IA* Intercostal artery, *BA* bronchial artery, *AV* aberrant vessel, *Lung* lung parenchyma, *unknown bleeding point

operation was 11 ± 8 days. The mean observation period was 1140 ± 1092 days. Four patients died from lung cancer ($n=1$) and other causes ($n=3$).

Relationship between the bleeding point and an increased amount of drained bloody effusion per hour

The intervals between operations are shown in Fig. 1. Patients were divided into three groups: in group 1 ($n=3$), re-exploration was decided rapidly and performed within 2 h (red bars in Fig. 1); in group 2 ($n=5$), re-exploration was decided following several hours to one day of careful observation (orange bars in Fig. 1); and in group 3 ($n=1$), re-exploration was performed for sudden-onset bleeding after over a week of observation.

In addition, we plotted the relationship between the amount of drained bloody effusion and the time after the end of the first operation as far as possible (Fig. 2). Case 1 was excluded from this analysis because a chest drain was not inserted before the second operation. This figure shows various patterns of bleeding. The volume drained per hour was not necessarily constant; for example, bleeding from the intercostal and bronchial arteries showed a high drainage rate. There was a case of bleeding from the intercostal artery in which bleeding suddenly occurred following drainage at a

low rate over 6 h. For a comparison, the volume drained per hour was constant in cases of bleeding from the lung parenchyma. In the two cases in which a second operation was scheduled after 15 h of observation, the bleeding points were not found (*attached in Fig. 2). These patterns of bleeding resembled those of bleeding from the lung tissue.

Case presentation

Case 1

A 68-year-old man with lung cancer and severe emphysema was introduced to our hospital. He had taken medication of warfarin for atrial fibrillation. Wedge resection of the right upper lobe of the lung was performed as a limited operation for lung cancer. For pulmonary stapling, a Duet TRS™ (Covidien, Mansfield, MA, USA) was used because stapling was to be performed on an emphysematous lung. He was discharged on postoperative day 11. However, he was transported to our emergency room on postoperative day 13 with a complaint of sudden-onset dyspnea. We diagnosed him with hypovolemia and hemothorax.

Emergency surgery was performed. After the removal of a large amount of clotting, arterial bleeding from the chest wall was found. The parietal pleura was partly abrasive, and bleeding from the exposed fourth intercostal artery was recognized (Fig. 3a). The bleeding was easily managed by ligation (Fig. 3b). We suspected that the bleeding was induced by scratching the thoracic wall with the edge of the reinforced stapling line for wedge resection at the first operation (Fig. 3c, d). Therefore, the reinforced stump was trimmed and covered with a soluble tissue sealing sheet. The operation time was 122 min. The amount of the clotting and bleeding was 5399 g. The patient was discharged on postoperative day 23 following the induction of home oxygen therapy. There has been no recurrence for 7 years and 6 months.

Case 2

A 56-year-old man with lung cancer without any complications was introduced to our hospital. He underwent right lower lobectomy. For the bronchial stapling, Echelon™ (ETHICON Endo-Surgery, Cincinnati, OH, USA) was used

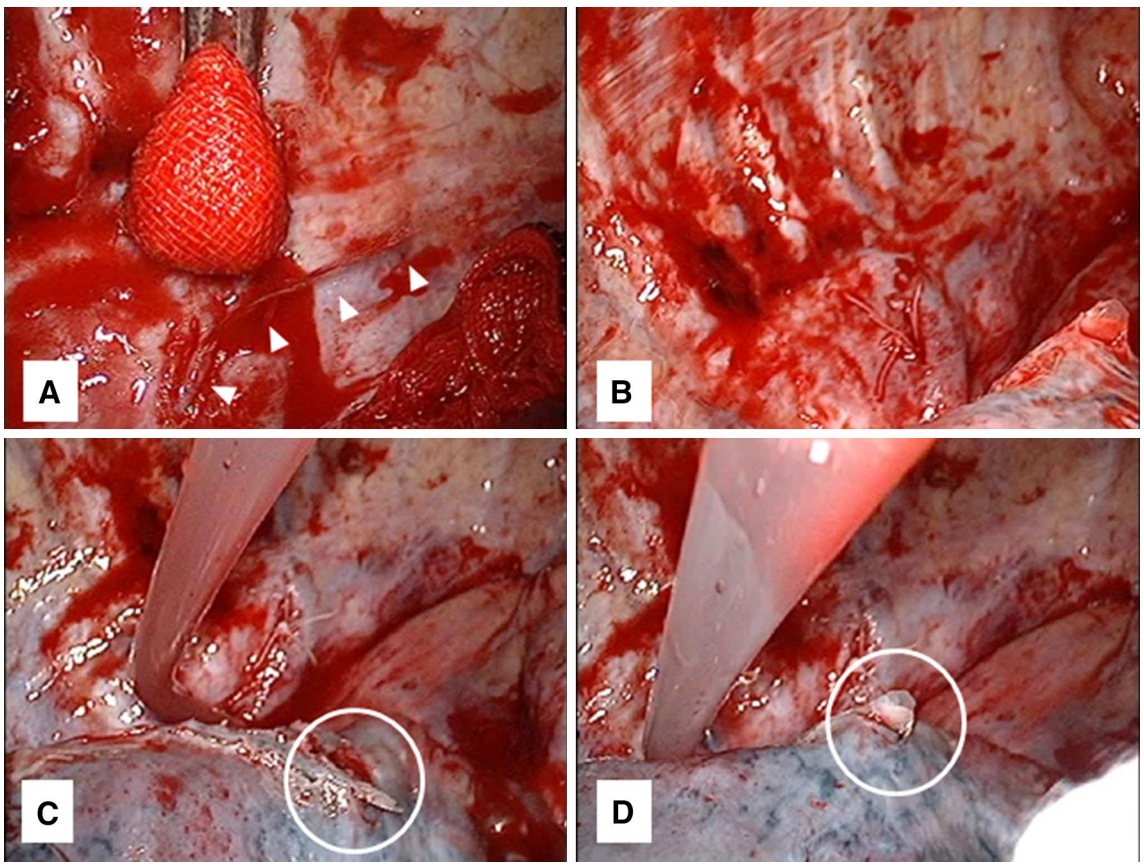

Fig. 3 A case with postoperative bleeding from the intercostal artery induced by the edge of the reinforced stapling line. **a** Arrowheads indicate the fourth intercostal artery and arterial bleeding. **b** Hemostasis by ligation of the artery. **c, d** Circles indicate the edge of the reinforced stapling line at the first operation

with a green cartridge. After the patient was moved to the recovery unit, bloody effusion appeared. Hemothorax was detected on chest X-ray. Reoperation was performed following the preparation of the operation room. After removing a large amount of clotting, arterial bleeding from the vertebra was found (Fig. 4a). The sixth intercostal artery was injured by the sharp edge of a broken staple (Fig. 4b, c). Bleeding was managed by electrocautery. The protruding edge of the broken staple was trimmed and covered with a soluble tissue sealing sheet (Fig. 4d). The operation time was 78 min. The amount of clotting and bleeding was 1236 g. The patient was discharged on postoperative day 5.

Discussion

We investigated cases of perioperative reoperation for postoperative bleeding. Postoperative bleeding has been considered the main cause of perioperative reoperation [1]. Recently, the incidence has decreased to around 1%, a value similar to that in the present study (Table 3) [2–4]. This reduction may be due to advances in surgical procedures, such as the introduction of minimally invasive surgery, sealing devices (e.g., LigaSure Maryland® [Covidien]), and hemostatic agents (e.g., TachoSil® [Nycomed Austria GmbH, Linz, Austria]).

We were fortunately able to cure all ten cases, including the patient with catastrophic bleeding as described above. In the same period, blood transfusion was performed in 29 cases, excluding these ten cases, because of intraoperative and postoperative bleeding (2.5% of 1143 cases). These cases did not meet our criteria of reoperation for postoperative bleeding. It was not certain in these 29 patients if reoperation could be omitted by transfusion.

The common bleeding points were mainly divided into two sites: the arteries and pulmonary parenchyma [1, 2, 4, 5]. The intercostal and bronchial arteries were considered the main sites of arterial bleeding in previous reports [1, 2, 4, 5]. We experienced bleeding from these arteries in the present study. In such cases, a second operation was rapidly decided upon because of the high rate of drained bloody effusion per hour. However, we experienced a case of bleeding from the intercostal artery in which sudden bleeding occurred following drainage at a low rate for 6 h. In addition, we

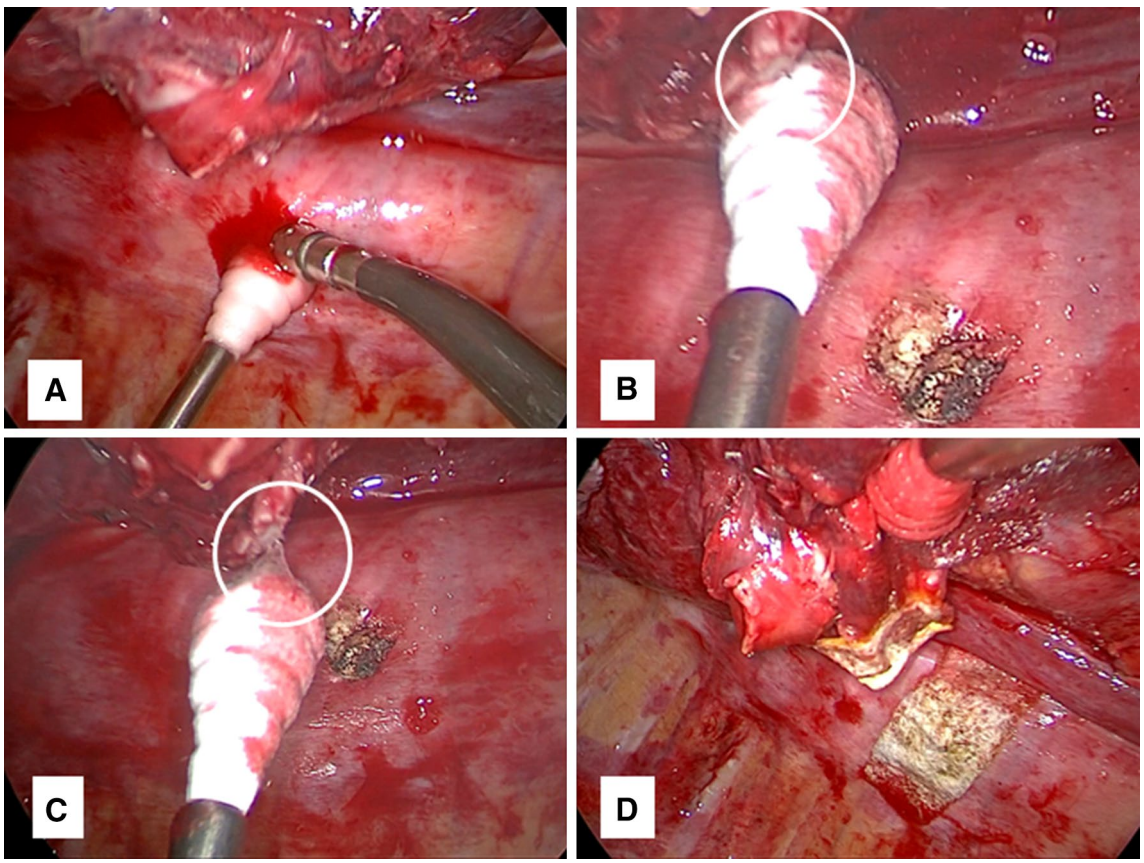

Fig. 4 A case with postoperative bleeding from the intercostal artery induced by the sharp edge of a broken staple. **a** Compression of intercostal arterial bleeding. **b** The sharp edge of a broken staple, like a needle. **c** Fibers from a cotton swab became tangled in the sharp edge of the broken staple. **d** The protruding edge was trimmed and covered with a soluble tissue sealing sheet

Table 3 Reports of postoperative bleeding following thoracotomy

No.	Reporter	Number of surgical cases	Number of cases with rethoracotomy for bleeding	Incidence (%)	Bleeding source			Mortality (%)
					Major vessels or heart	Minor vessels or wound	Unknown	
1	Péterffy and Henze [1]	1428	40	2.8	11 (27.5%)	28 (70.0%)	1 (2.5%)	22.5
2	Sirbu et al. [2]	1960	38	1.9	7 (18.4%)	21 (55.3%)	10 (26.3%)	15.7
3	Solaini et al. [5]	–	16	–	0 (0%)	13 (81.2%)	3 (18.8%)	0
4	Foroulis et al. [3]	719	9	1.3	–	–	–	0
5	Yang et al. [4]	19,304	143	0.7	2[a] (1.4%)	111[a] (77.6%)	29[a] (20.3%)	2.8
6	Our study	805	9	1.1	0 (0%)	7 (77.7%)	2 (22.2%)	0

[a]The number of accumulated cases did not equal 143

experienced bleeding from an aberrant artery that bridged the parietal and visceral pleura at the apex of the lung. To prevent such bleeding, aberrant arteries should be managed during the first operation. However, we did not detect this aberrant vessel during the first operation. We experienced two cases of bleeding from the pulmonary parenchyma. Rupture of the pulmonary stapling line in both cases was recognized at the second operation. Though this complication may have been induced by stapler–tissue thickness mismatch and tissue fragility [6], there were no such description in the operation record. In such cases, the second operations have been decided following a relatively long observation period (within 12 h). The rates of drained bloody effusion were relatively uniform. Furthermore, in two of ten cases (Table 2), we failed to identify the bleeding point, a rate that was almost the same as in previous reports [2–4]. In such cases, wide adhesion was observed in the first operation, resulting in a relatively large amount of intraoperative bleeding on dissection of the adhesion. One patient had been taking warfarin for atrial fibrillation preoperatively. In two cases with a low coagulation ability following the administration of anticoagulation medication and blood loss from the primary operation, the bleeding point was not found. In both cases, it took a long time to decide to perform the second operation (Fig. 2). The rates of drained bloody effusion were relatively uniform, similar to cases with bleeding from lung parenchyma. In cases without a clear bleeding point, we only explored the thoracic cavity and removed the clot. Following sufficient observation, we closed the thoracic cavity. We believe that there is as advantage in re-exploration to decrease the opportunity of pyothorax with removing massive clot even if we could not find bleeding point.

We experienced no cases of bleeding from major vessels like the pulmonary arteries or veins that were ligated or stapled in lobectomy. This differs from initial reports [1, 2] and it may be a reason that we could cure all ten cases. It may be due to technological advances in staplers and their widespread usage. Staplers have become usual tools in thoracic surgery. Yano et al. recently reported a low rate of adverse events for pulmonary vessel stapling (0.27%) [7]. The incidence of postoperative bleeding in cases of pulmonary vessel stapling was only 0.03% [7], making it a relatively rare complication. The lower incidence of bleeding from the major pulmonary vessels may lead to a reduced incidence of mortality following postoperative bleeding (Table 3).

However, we experienced four cases of bleeding concerning stapling wherein the bleeding was not from a major pulmonary vessel. As described in case 1, the reinforced edge of the stapling line by Duet TRS™ injured the intercostal artery. The Duet TRS™ had since been prohibited from usage in thoracic surgery because the reinforced material covering the stapling line was too hard and risked injuring the adjacent organs or tissues. Similar cases of bleeding induced by the edge of the bronchial stump have been reported [8, 9]. We have recognized that such bleeding by the edge of stapler become a thing of the because the usage of Duet TRS™ was already prohibited. However, we have experienced a similar case recently (case 2). In case 2, stapling for the bronchus was used an usual stapler without reinforcement. However, a tip of a broken staple became a sharp needle and injured the intercostal artery. We again recognize the possibility that postoperative bleeding can be induced by stapling failure and underscore the importance of carefully observing the stump of the stapled tissues.

Conclusion

We were able to cure all ten cases with postoperative bleeding. It might be dependent on the rapid decision of reoperation for cases with arterial bleeding. To decrease the incidence of postoperative bleeding, it is important to understand the causes and factors influencing such postoperative bleeding.

Compliance with ethical standards

Conflict of interest All authors declare no conflicts of interest in the present study.

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