J Anesth (2011) 25:426–430
DOI 10.1007/s00540-011-1120-9

CLINICAL REPORT

Nitrogenous subcutaneous emphysema caused by spray application of fibrin glue during retroperitoneal laparoscopic surgery

Shinji Matsuse · Atsushi Maruyama · Yoshiki Hara

Received: 26 December 2010 / Accepted: 22 February 2011 / Published online: 22 March 2011

Abstract We report a case of a patient treated by retroperitoneoscopic partial nephrectomy who developed nitrogenous subcutaneous emphysema (SCE) as a complication. The use of a nitrogen gas-pressured fibrin tissue adhesive applied as a spray caused excessively increased pressure in the closed retroperitoneal space and resulted in widespread SCE with protracted clinical course. To the best of our knowledge, this is the first report of nitrogenous SCE associated with pneumoperitoneum. The clinical significance of nitrogenous SCE is emphasized, and the risks associated with the use of fibrin glue as a spray during laparoscopic surgery are discussed.

Keywords Subcutaneous emphysema · Fibrin glue · Nitrogen · Spray · Retroperitoneal laparoscopy

Introduction

Subcutaneous emphysema (SCE) and hypercapnea/hypercarbia are well-known complications associated with scopic surgery under carbon dioxide (CO_2) insufflation [1]. In retroperitoneoscopic surgeries, the incidence of SCE is high (45% in retroperitoneoscopic vs. 12.5% in laparoscopic surgery [2]) probably due to the dissecting procedures used to produce extra-peritoneal space [3]. However, SCE associated with CO_2 insufflation usually resolves without further treatment due to the high solubility of the gas in the body [4].

Fibrin tissue adhesives (FTA) are useful for hemostasis in various surgical procedures [5, 6]. Although fibrin sealants are more effective if sprayed rather than dripped onto the surface [7], aerosol adhesives have not been authorized for use in laparoscopic procedures with insufflation in Japan [8]. Most of the applicators for FTA supplied by manufacturers are compatible with either the compressed air or nitrogen gas supply unit despite the poor solubility in the tissue relative to that of CO_2. The reason for this is that such units are widely used as the primary pressure source for pneumatic devices in operating rooms throughout Japan. Here, we describe a patient who developed widespread nitrogenous SCE and pneumoperitoneum immediately after the insertion of the spray applicator into the closed retroperitoneal space.

Case report

Our Institutional Review Board (IRB) determined that we did not require IRB review and specific permission for this report. Permission to present the case was obtained from the patient.

The patient was a 57-year-old woman (height 151 cm, weight 58 kg), American Society of Anesthesiologists (ASA) physical status I, who was scheduled to undergo retroperitoneoscopic right partial nephrectomy for right renal cancer. She did not receive any pre-medication on the day of the operation. On arrival in the operating room, routine monitors were applied [electrocardiogram (ECG), non-invasive arterial pressure, and pulse oximetry)]. A left radial arterial line was placed for invasive arterial pressure

S. Matsuse (✉) · A. Maruyama · Y. Hara
Department of Anesthesia, Kasukabe-chuo General Hospital, Midori-cho 5-9-4, Kasukabe, Saitama 344-0063, Japan
e-mail: shinjimat@hotmail.com; shinjimat@yahoo.co.jp

S. Matsuse
Department of Emergency and Critical Care Medicine, Graduate School of Medicine, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8655, Japan

monitoring and blood collection for analysis. An intravenous infusion of acetated Ringer's solution was started in the right forearm and administered at 8–10 ml/kg/h. An epidural catheter was inserted via the intervertebral space between thoracic levels 10 and 11. A test dose of 2 ml of ropivacaine 0.3% was injected into the epidural space followed by a bolus of 0.1 ml/kg ropivacaine 0.3% and 50 μg fentanyl. General anesthesia was introduced with intravenous fentanyl 1 μg/kg and propofol 1.5 mg/kg while the patient received 100% oxygen by face mask. The neuromuscular block was achieved with vecronium bromide 0.1 mg/kg. The trachea was intubated with a 7.5-mm endotracheal tube (Mallinckrodt, Covidien Japan, Tokyo, Japan). General anesthesia was maintained with inhalation of 2% sevoflurane in an air–oxygen mixture at 5 l/min, adjusted to maintain 60% inspired oxygen. The lungs were ventilated in volume-controlled mode. Tidal volume and respiratory rate were adjusted based on continuous end tidal CO_2 monitoring (Multi gas unit AG920R; Nihonkhoden, Tokyo, Japan). The end tidal CO_2 was calibrated to arterial CO_2 prior to surgery. Ventilation was adjusted intraoperatively to maintain the arterial CO_2 partial pressure at 40 ± 5 mmHg.

The operation was performed with the patient left side down, and a distension balloon (PDB balloon; The PDB System, Covidien/US Surgical, Norwalk, CT) was used to separate tissue planes, forming a discrete cavity. Following tissue separation, a second cannula with a balloon anchor (Blunt Tip Trocar; The PDB System, Covidien/US Surgical) was inserted into the cavity, and the extraperitoneal space was insufflated with CO_2 to maintain an intra-abdominal pressure between 8 and 10 mmHg. After an initial modest rise, a steady level of end-tidal CO_2 tension was maintained without exceeding the peak intra-airway pressure of >20 cmH_2O throughout the operation.

The procedure was unremarkable until urologists initiated spray application of a nitrogen gas-pressured (0.08 MPa = 0.8 bar) FTA on the cut surface of the right kidney. Immediately following the insertion of the applicator, the insufflator sounded the alarm, and an intra-airway pressure gauge indicated a peak pressure >35 cmH_2O. None of the trocar vents were open at the time; these were then opened and the applicator removed immediately. Careful examination of the patient revealed that she had developed SCE extending from the abdominal wall to the neck, particularly on her right side. The operative procedure was continued and completed without any abnormalities in terms of vital signs; the total time for the operation and the anesthesia were 4 h 30 min and 6 h, respectively. Even though the postoperative chest radiograph (Fig. 1) did not show pneumothorax or pneumomediastinum, she was not extubated in the operating room because of the risk of upper airway obstruction. Her vital signs were stable, and she was transferred to the intensive care unit for further surveillance. Her SCE gradually subsided, and her tracheal tube was removed on the 2nd postoperative day (POD) after sufficient resolution of SCE around her neck had been confirmed on the chest radiograph (Fig. 2). Abdominal computed tomography (CT) scan (Fig. 3) of the patient revealed significant pneumoperitoneum and SCE in the abdominal wall on POD 5 which had not distinctly decreased between POD 5 and POD 8. The patient made an uneventful recovery without further complications and was discharged from hospital on POD 14. Although she did not present any symptoms on

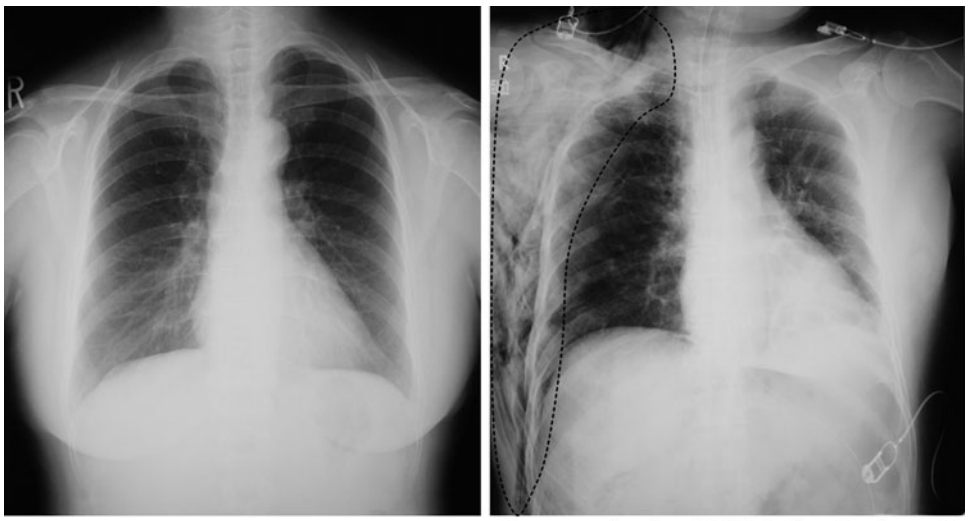

Fig. 1 Pre-operative (*left*) and postoperative (*right*) chest radiographs. Postoperative portable chest radiograph (POD 0) demonstrating marked subcutaneous emphysema (SCE) in the chest and neck on the right side (*encircled in black dotted line*). There was no pneumothorax or pneumomediastinum. *POD* Postoperative day

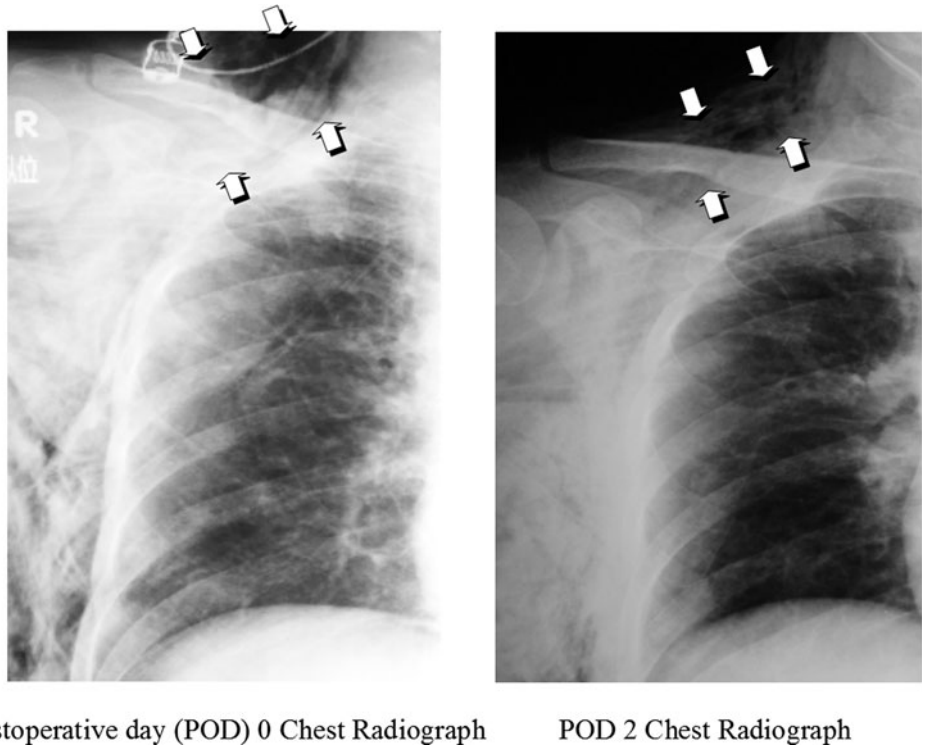

Fig. 2 Chest radiographs of the day of the operation (*POD 0*, *left*) and the second postoperative day (*POD 2*, *right*). Note that the area of SCE on the right shoulder and neck on POD 0 had significantly diminished by POD 2 (*delineated with arrows*)

the follow-up visit on POD 30, her abdominal CT scan still showed remnant pneumoperitoneum.

Discussion

FTA, also known as fibrin glue, fibrin sealant, among other terms, is used for hemostasis in a variety of surgical procedures and is especially useful in heparinized patients undergoing cardiovascular procedures since it does not require an intact hemostatic system to be effective [9]. When injected, the purified fibrinogen and thrombin extract merge just before they reach the targeted surface, resulting in hemostasis and faithful replication of the physiological final common pathway of coagulation, i.e., the thrombin-mediated enzymatic conversion of fibrinogen to fibrin, to replicate the formation of a fibrin clot [10].

FTA can be used either drop by drop or continuously by spraying. When used in spray form, a sterile propellant gas (either compressed air, nitrogen gas, or CO_2 gas is used, depending on availability) is passed through the tubing to the spray head and independently controlled, allowing for drying of the tissue surface [5]. However, the spray form is authorized for use only for the open circuit system, such as thoracoscopic operations; it is prohibited for use in laparoscopic procedures with insufflation and/or on surfaces with active bleeding due to the risks of excessively high intra-abdominal pressure and gas embolism, respectively [11]. Therefore, it is mandatory that special precautions be closely adhered to (e.g., open the trocar vent in order for the cavity to equilibrate with the atmospheric pressure, carefully monitor the intra-abdominal pressure and hemodynamics, and keep the spray periods short [8]).

SCE occurs when a specific gas is present in the subcutaneous layer of the skin. It usually does not require any special treatment since this small amount of gas is readily reabsorbed by the body. However, its presence can be uncomfortable and may interfere with breathing when the condition develops rapidly, sometimes even causing cardiopulmonary collapse [12, 13]. The patient in our case was not extubated in the operating room because massive SCE involving the neck could cause airway compromise by swollen pharyngeal tissue [4, 14]. High insufflation pressure is an independent risk factor for the development of SCE [4], and the use of adhesives in spray form in laparoscopic procedures exacerbates an accumulation of high intra-abdominal pressure. Schmidt et al. [15] reported the case of a patient who underwent laparoscopic extraperitoneal repair of inguinal hernia. Even though a trocar was intermittently opened and the preperitoneal space desufflated in order not to exceed 30 mmHg of intra-abdominal pressure during the spray application, the patient was later found to have mild SCE. The propellant gas used in this patient was CO_2, and the patient did not complain of any symptom; the SCE disappeared rapidly without any treatment. Since the extraperitoneal cavity is "artificially created" and is therefore less compliant to pressure changes and highly susceptible to the development of SCE, the

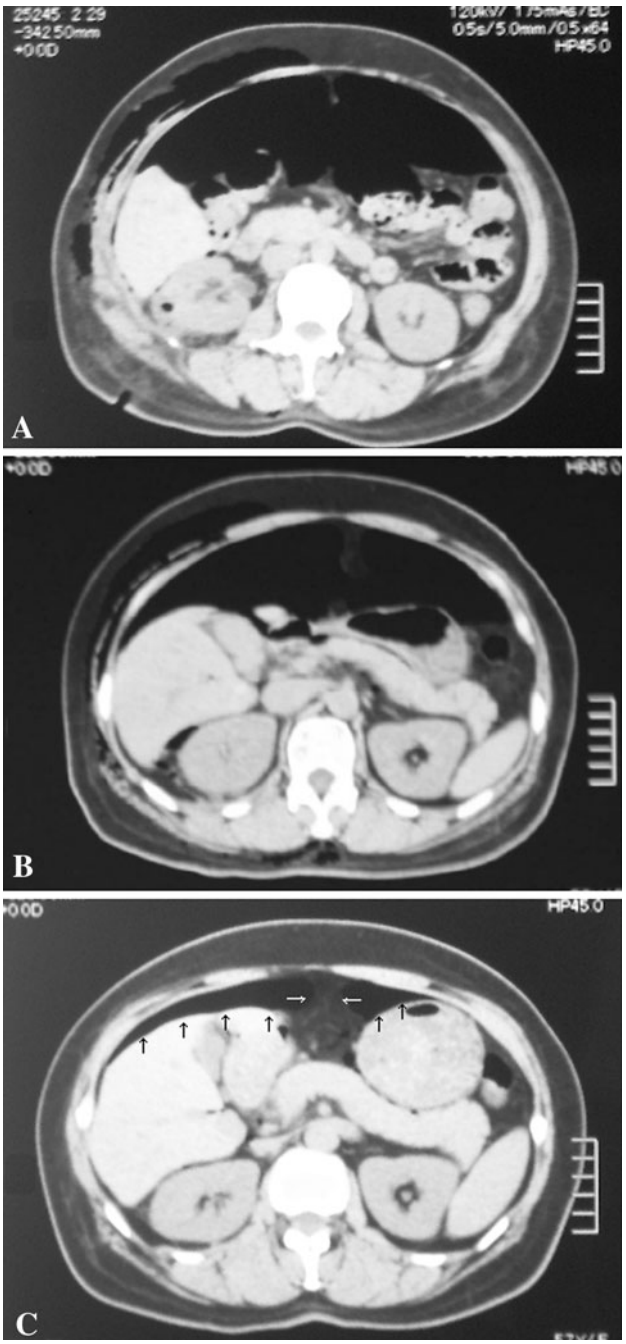

Fig. 3 Computed tomography images of the abdomen from the patient on the POD 5 (**a** *upper*), 8 (**b** *middle*), and 30 (**c** *lower*). **a**, **b** Severity of SCE and pneumoperitoneum had not changed obviously from POD 5 to POD 8. **c** SCE in abdominal wall had completely disappeared by POD 30. Surprisingly, mild pneumoperitoneum still remained above the liver and bowel (*black arrows*). The falciform ligament was surrounded by air on either side (*white arrows*)

application of gas-propelled fibrin glue in spray form into the closed extraperitoneal space must be avoided, even with a proper desufflation.

An abdominal CT scan is useful to evaluate the slower resolution process of her SCE due to relative insolubility of nitrogen. Although her stable vital signs and the lack of pneumomediastinum or pneumothorax did not warrant further treatment, negative pressure wound therapy could have expedited the resolution of her nitrogenous SCE [16, 17]. Gas embolism, although uncommon (0.0014%) [18], is another such complication and is recognized to have a high mortality rate (28.5%) [19]. The high solubility of CO_2 and the buffering capacity of blood for CO_2 account for its 40-fold higher solubility in blood compared to nitrogen (0.646 vs. 0.016 mL gas/mL blood) [20, 21]. In this context, small amounts of soluble gas (CO_2) embolism probably occur frequently and have no clinical consequence, while smaller amounts of insoluble gas (air, nitrogen) may cause fatal gas embolism [4, 22]. Since it is virtually impossible to eliminate the risks of SCE or gas embolism, it is advisable to avoid the use of compressed air or nitrogen gas as a propellant of fibrin glue spray.

References

1. Murdock CM, Wolff AJ, Geem TV. Risk factors for hypercarbia, subcutaneous emphysema, pneumothorax, and pneumomediastinum during laparoscopy. Obstet Gynecol. 2000;95:704–9.
2. Ng CS, Gill IS, Sung GT, Whalley DG, Graham R, Schweizer D. Retroperitoneoscopic surgery is not associated with increased carbon dioxide absorption. J Urol. 1999;162:1268–72.
3. Hirsch IH, Moreno JG, Lotfi MA, Gomella LG. Controlled balloon dilatation of the extraperitoneal space for laparoscopic urologic surgery. J Laparoendosc Surg. 1994;4:247–51.
4. Ludwig KA. Implications of subcutaneous emphysema and how to avoid and/or limit its development. In: Whelan RL, Fleshman JW, Fowler DL, editors. The Sages manual. New York: Springer; 2006. p. 273–80.
5. Shekarriz B, Stoller ML. The use of fibrin sealant in urology. J Urol. 2002;167:1218–25.
6. Kram HB, Shoemaker WC, Clark SR, Macabee JR, Yamaguchi MA. Spraying of aerosolized fibrin glue in the treatment of nonsuturable hemorrhage. Am Surg. 1991;57:381–4.
7. Druckrey-Fiskaaen KT, Janssen MW, Omidi L, Polze N, Kaisers U, Nur I, Goldberg E, Bokel G, Hauss J, Schön MR. Laparoscopic spray application of fibrin sealant effects on heamodynamics and spray efficiency at various application pressures and distances. Surg Endosc. 2007;21:1750–9.
8. Umegaki T, Nishi K, Murao K, Takahira K, Shingu K. Lethal air embolism after spray of tissue adhesive-fibrinogen and factor XIII aerosol during laparoscopic partial nephrectomy (in Japanese with English adstract). Masui (Jpn J Anesthesiol). 2007;56:1203–5.
9. Thompson DF, Letassy NA, Thompson GD. Fibrin glue: a review of its preparation, efficacy, and adverse effects as a topical hemostat. Drug Intell Clin Pharm. 1988;22:946–52.
10. Atrah HI. Fibrin glue. Br Med J. 1994;308:933–4.
11. Olsen PS, Hjelms E. Intravascular air after fibrin sealing by spray gun in cardiovascular surgery. Eur J Cardiothorac Surg. 1989;3:376–7.

12. Imai H, Nakatani N, Matsuda S, Murakawa K, Tashiro C. Sudden difficulty in ventilation due to massive subcutaneous emphysema during laparoscopic cholecystectomy (in Japanese with English abstract). Masui (Jpn J Anesthesiol). 2005;54:658–61.
13. Lehmann LJ, Lewis MC, Goldman H, Marshall JR. Cardiopulmonary complications during laparoscopy: two case reports. South Med J. 1995;88:1072–5.
14. Yagihashi Y, Okinami T, Fukuzawa S. Case of pharyngeal emphysema with airway obstruction during retroperitoneal laparoscopic nephroureterectomy (in Japanese with English abstract). Nippon Hinyokika Gakkai Zasshi (Jpn J Urol). 2009;100:540–4.
15. Schmidt SC, Langrehr JM. Re: Spray application of fibrin glue as risk factor for subcutaneous emphysema in laparoscopic transabdominal inguinal hernia repair. Surg Laparosc Endosc Percutan Tech. 2007;17:221–2.
16. Sciortino CM, Mundinger GS, Kuwayama DP, Yang SC, Sussman MS. Case report: treatment of severe subcutaneous emphysema with a negative pressure wound therapy dressing. Eplasty. 2009;9:e1.
17. Beck PL, Heitman SJ, Mody CH. Simple construction of a subcutaneous catheter for treatment of severe subcutaneous emphysema. Chest. 2002;121:647–9.
18. Bonjer HJ, Hazebroek EJ, Kazemier G, Giuffrida MC, Meijer WS, Lance JF. Open versus closed establishment of pneumoperitoneum in laparoscopic surgery. Br J Surg. 1997;84:599–602.
19. Cottin V, Delafosse B, Viale JP. Gas embolism during laparoscopy: a report of seven cases in patients with previous abdominal surgical history. Surg Endosc. 1996;10:166–9.
20. Priestley JG, Schwarz H. The solubility of acetylene in blood. I. Determination of acetylene dissolved in blood or other liquids. J Physiol. 1940;99:49–56.
21. Schulze T, Kumpf O, Rau B. Massive subcutaneous emphysema after thoracoscopic argon beamer use for pleurodesis. Surg Laparosc Endosc Percutan Tech. 2005;15:252–5.
22. Magrina JF. Complications of laparoscopic surgery. Clin Obstet Gynecol. 2002;45:469–80.