Inserting a Drainage Strip into the Pre-tracheal Space to Treat Tension Pneumomediastinum: A Case-control Study

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Abstract

Background: A Severe tension pneumomediastinum can result in respiratory and circulatory dysfunction. Common etiologies include severe pneumonia such as COVID-19 pneumonia, asthma, excessive pressure from a ventilator, etc. we describe a method for draining tension pneumomediastinum by inserting a drainage strip into the pre-tracheal space.

Methods:

Design: Case-control.

Setting: Data from a medical institution in southern China.

Participants: 30 patients with tension pneumomediastinum and comorbid type II respiratory failure.

Interventions: 15 patients (surgery group) were treated with a drainage strip being inserted into the pre-tracheal space while other 15 patients (control group) were treated without drainage.

Outcome measures: Arterial blood pO_2 and pCO_2 after 30 minutes and 12 hours of mechanical ventilation, total duration of mechanical ventilation, and chest radiography results after 12 hours of mechanical ventilation.

Results: Chest radiography after 12 hours of mechanical ventilation showed that the pneumomediastinum basically disappeared in the surgery group but did not decrease significantly in the control group. The arterial blood pCO_2 after 12 hours of mechanical ventilation and total duration of mechanical ventilation were significantly lower in the surgery group than in the control group (95% CI -3.31 to -1.36, $p<0.001$; 95% CI -5.56 to -2.84, $p<0.001$), while the arterial blood pO_2 after 12 hours of mechanical ventilation was significantly higher in the surgery group than in the control group (95% CI 1.76 to 7.57, $p=0.004$). There were no significant intergroup differences in other variables. No recurrence occurred in either group during 7–14 days after discharge, and all patients recovered.

Conclusions: Our method for draining tension pneumomediastinum improved respiratory function and shortened mechanical ventilation duration.

Trial registration: ChiCTR2000039496

Data sharing statement: Technical appendix, statistical code, and dataset available from the FigShare repository, https://doi.org/10.6084/m9.figshare.13487295.

Introduction

Pneumomediastinum occurs when air enters the mediastinal connective tissue space after alveolar wall rupture. It can simultaneously cause subcutaneous gas accumulation in the suprasternal fossae, supraclavicular fossae, lateral chest wall, etc. Common etiologies include severe pneumonia such as COVID-19 pneumonia, asthma, excessive pressure from a ventilator, abdominal trauma or surgery, etc (1, 2). Mild and moderate cases without obvious respiratory dysfunction or circulatory dysfunction can be cured by inhaling oxygen, analgesic, antibiotics and waiting for the body to absorb. However, in severe cases, accumulation of large amounts of gas in the mediastinum can cause relatively large tension, leading to compression symptoms similar to tension pneumothorax. This compresses the lung tissue, resulting in dyspnea, and also compresses the mediastinal vena cava, thus impeding blood flow back to the heart and causing circulatory dysfunction (3, 4, 5). This condition requires timely gas expulsion and decompression. Although there have been reports of thoracoscopic treatment, however, this is usually achieved by using a thick needle for puncture or using a scalpel to make small incisions in the skin corresponding to the site of pneumomediastinum to release gas, or making a single incision and then inserting a subcutaneous drainage strip for drainage (3, 4, 6). Few papers describe these methods in a normative manner. This paper combines the local anatomical characteristics to describe a method for draining tension pneumomediastinum. We present the following article in accordance with the STROBE reporting checklist.

Methods

Criteria, defines and data sources

We retrospectively analysed the treatment of patients whose inclusion criteria were: 1) treated in our hospital between 2014 and 2021; 2) tension pneumomediastinum; and 3) type II respiratory failure.

Exclusion criteria were: 1) asthmatic attack; 2) the bullae of lung ruptured; 3) the cystadenoma of lung was obviously distended; 4) combined heart disease. The tension pneumomediastinum in these four conditions cannot be eliminated by simple drainage or by waiting for the body to absorb it, so they are confounding factors and should be excluded.

The descriptions of Kouritas and Clancy were used as the definition of tension pneumomediastinum: accumulation of large amounts of gas in the mediastinum causes relatively large tension, leading to compression symptoms similar to tension pneumothorax. It compresses the lung tissue, resulting in dyspnea, and also compresses the mediastinal vena cava, thus impeding blood flow back to the heart and causing circulatory dysfunction (3, 7).

Arterial blood pO2 and pCO2 were obtained by bedside blood gas analysis and, because they directly reflect changes in respiratory function, served as predictors of changes in pneumomediastinum. The changes of pneumomediastinum were directly observed by bedside chest radiograph.

Type II respiratory failure: arterial blood pO2 < 8.0Kpa (60mmHg) and pCO2 > 6.7Kpa (50mmHg).

Grouping and Statistics

Patients were divided into surgery group and control group based on whether or not drainage was performed. Since body develops with age, the two patient groups were paired 1:1 by similar age. We compared the baseline data, arterial blood pO_2 and pCO_2 after 30 minutes and 12 hours of mechanical ventilation, total duration of mechanical ventilation, and chest radiography results after 12 hours of mechanical ventilation between groups.

After discharge, all patients were followed up for 7–14 days.
SPSS 22 software (IBM SPSS Statistics, RRID:SCR_019096) was used to perform paired t-tests of measurement data, and count data were analyzed by Chi-square. P < 0.05 indicated statistical significance. (Fig. 1)

We controlled for selective bias by strictly enforcing inclusion and exclusion criteria, and controlled for information bias by having all authors collect all data independently and check against each other.

Drainage procedure in surgery group

 The left and right angles of the rhombic region encircled by the anterior borders of the left and right sternocleidomastoid muscles and the sternohyoid muscles were used as the positions of the left and right incisions, and were indicated on the skin using a marker (Fig. 2). We used sterile rubber gloves to make drainage strips with a width of 1.5cm and a length that were 3cm longer than the distance between the two incisions. After routine skin disinfection and laying of surgical drapes, we used a scalpel to make 5-mm longitudinal incisions at the left and right skin marks. Curved forceps were inserted into the right incision for blunt dissection of subcutaneous tissues. The superficial fascia of the neck was punctured. At this point, there was a feeling of emptiness after penetration. Subsequently, the forceps were inserted into the pre-tracheal space and a blunt dissection of the pre-tracheal space from right to left was made until the site of the left (contralateral) incision was reached. The superficial fascia of the neck was punctured from the medial to the lateral side, and the forceps came out through the left incision. During blunt dissection of the pre-tracheal space, we palpated the trachea with our fingers to determine its position and to avoid damaging it (Fig. 3). We used the end of the curved forceps outside the left incision to clamp one end of the pre-made rubber drainage strip and the forceps were slowly withdrawn from the dissection tunnel, thereby introducing the drainage strip slowly into the tunnel. We left 1.5cm of the drainage strip outside each of the two incisions to ensure that the ends of the drainage strip would not easily slip into the subcutaneous tissue. We disinfected and bandaged the incision site. Chest radiography was carried out 12 hours later. If no significant pneumomediastinum was found, the drainage strip was removed 1–3 days later without the need for suturing the incision site.

Results

The surgery group included 15 patients treated in our hospital between January 2018 and November 2020 in whom a drainage tube was inserted into the pre-tracheal space to drain the pneumomediastinum after the arterial blood gas analysis results were obtained. The control group included 15 patients treated in our hospital between March 2014 and December 2017 in whom no drainage tube was placed after the arterial blood gas analysis results were obtained. All patients received endotracheal intubation and mechanical ventilation. After 30 minutes of mechanical ventilation, blood oxygen saturation, at above 75%, was not stabilised, and arterial blood gas analysis showed a low partial pressure of oxygen (pO_2) and a high partial pressure of carbon dioxide (pCO_2). Arterial blood gas analysis and chest radiography were repeated for all paediatric patients after 12 hours of mechanical ventilation. Patients were weaned from mechanical ventilation once chest radiography showed that the pneumonia was controlled. The ventilator parameters were gradually decreased to an oxygen concentration ≤ 30%, oxygen flow rate ≤ 1.5 L/min, and respiratory rate ≤ 35 bpm. There were no significant intergroup differences in sex (p = 0.705), age

(95% CI -4.68 to 4.15, p = 0.899), weight (95% CI -2.06 to 0.45, p = 0.194), arterial blood pO2 and pCO2 after 30 minutes of mechanical ventilation (95% CI -7.41 to 6.34, p = 0.870; 95% CI -0.28 to 2.95, p = 0.099). (Table 1)

Table 1
Baseline data, arterial blood pO2 and pCO2 after 30 minutes of mechanical ventilation

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CI	P value
Sex S[a]	M	F	F	M	M	F	M	F	M	M	M	F	F	M	M	–	–
Sex C[b]	M	M	M	F	M	M	M	F	F	M	M	M	F	F	M		0.705
Age S[a] (month)	132	40	29	22	10	115	8	17	2	11	65	20	15	3	4	–	–
Age C[b]	120	52	35	26	10	93	7	19	3	12	72	23	16	4	5	-4.68 to 4.15	0.899
Weight S[a] (kg)	35	14.5	13.7	12.2	8.7	29	9.5	10	5.5	10.6	19.7	11.7	10.4	6.8	7.2	–	–
Weight C[b]	30.5	20	14.5	13.8	9.5	27.4	9.3	10.8	7.9	11	23.5	12.7	9.6	7.6	8.4	-2.06 to 0.45	0.194
pO_2 1 S[a] (mmHg)	56	62	68	59	35	69	65	60	58	71	63	60	55	73	70	–	–
pO_2 1 C[b]	64	49	56	59	70	65	60	70	54	65	57	67	68	65	63	-7.41 to 6.34	0.870
pCO_2 1 S[a] (mmHg)	57	55	54	53	56	58	55	52	53	58	59	51	58	58	56	–	–
pCO_2 1 C[b]	56	53	55	55	54	50	53	52	54	52	56	53	55	57	58	-0.28 to 2.95	0.099

S[a]: Surgery group. C[b]: Control group. M:male. F:female. pO_2 1: Arterial blood pO_2 after 30 minutes of mechanical ventilation. pCO_2 1: Arterial blood pCO2 after 30 minutes of mechanical ventilation.

Chest radiography after 12 hours of mechanical ventilation showed that the pneumomediastinum basically disappeared in the surgery group but did not decrease significantly in the control group. The operative time ranged from 25 to 35 minutes (30.267 ± 2.932). No tracheal or vascular was damaged. The arterial blood pCO_2 after 12 hours of mechanical ventilation and total duration of mechanical ventilation were significantly lower in the surgery group than in the control group (95% CI -3.31 to -1.36, p < 0.001; 95% CI -5.56 to -2.84, p < 0.001), while the arterial blood pO_2 after 12 hours of mechanical ventilation was significantly higher in the surgery group than in the control group (95% CI 1.76 to 7.57, p = 0.004). There were no significant intergroup differences in follow-up (95% CI -1.95 to -0.55, p = 0.589). No recurrence occurred in either group during 7–14 days of follow-up, and all patients recovered. (Table 2)

Table 2
Post-operative data

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CI	P value
Duration 1 (minute)	28	25	35	30	27	33	31	26	32	31	31	34	31	27	33	–	–
pO_2 2 S[a] (mmHg)	72	76	79	71	69	80	78	73	75	82	79	80	68	83	77	–	–
pO_2 2 C[b]	68	66	72	65	75	72	74	76	68	73	70	75	73	73	72	1.76 to 7.57	0.004
pCO_2 2 S[a] (mmHg)	40	42	45	40	44	43	39	44	46	38	41	43	45	48	39	–	–
pCO_2 2 C[b]	45	45	46	44	46	43	42	44	46	42	45	46	47	48	43	-3.31 to -1.36	0.001
Duration 2 S[a] (day)	11	12	7	6	11	8	11	14	14	8	13	9	15	10	13	–	–
Duration 2 C[b]	17	19	14	14	15	13	12	16	15	11	18	16	17	11	17	-5.56 to -2.84	0.001
Follow-up S[a] (day)	7	11	8	7	12	9	10	11	12	10	11	7	8	10	12	–	–
Follow-up C[b]	9	7	10	9	8	7	14	9	11	10	9	12	11	12	13	-1.95 to -0.55	0.589

S[a]: Surgery group. C[b]: Control group. Duration 1: Duration of surgery. Duration 2: Total duration of mechanical ventilation. pO_2 2: Arterial blood pO_2 after 12 hours of mechanical ventilation. pCO_2 2: Arterial blood pCO_2 after 12 hours of mechanical ventilation.

Sample size calculation

The sample size was determined by the mean and standard deviation of the difference in the primary endpoint, total duration of mechanical ventilation. The paired design data is measurement data, and the difference is normally distributed ($W = 0.914$, $P = 0.158$, $\delta = -4.200$, $\sigma = 2.455$, Table 3), using paired t test, and sample size was calculated following the formula: $n=(t_\alpha+t_\beta)^2\sigma^2/\delta^2$ (8). At least 6 pairs were needed for testing.

Table 3
Primary endpoint in both groups: total duration of mechanical ventilation

	Surgery (M ± SD)	Control (M ± SD)	(Mean ± SD)	Normality test of differential value (W, P)	Statistic	P
MV	10.800 ± 2.757	15.000 ± 2.478	-4.200 ± 2.455	(0.914, 0.158)[d]	-6.625[a]	0.001

a, Paired-samples t test; d: Shapiro-Wilk test. MV, total duration of mechanical ventilation (day).

Discussion

The mediastinal space is a narrow space between organs in the mediastinum that is filled with loose connective tissue to accommodate organ activities and changes in volume. The connective tissues of the mediastinal space extend upwards and are continuous with the connective tissues of the neck. The pre-tracheal space is located between the upper mediastinum, trachea, bifurcation of trachea, and aortic arch. It communicates upward with the pre-tracheal space in the neck. Gas can diffuse upwards to the neck when pneumomediastinum occurs. A layer of superficial fascia exists between the mediastinal space and the skin. This layer of superficial fascia is dense and gas cannot easily diffuse through it. The pre-tracheal space lies behind the superficial fascia of the neck, in a rhombic region formed between the anterior borders of the bilateral sternocleidomastoid muscles and the anterior borders of the bilateral sternohyoid muscles. This area contains the anterior jugular vein, the jugular venous arch, and the inferior thyroid vein. When performing this procedure, blunt dissection must be used to reduce the risk of injury to these veins (9).

It is much more difficult to control the anatomical layer accessed by the incision when using a needle or small incision to expel gas. Thus, the superficial fascia may not be punctured due to fear of causing vascular and nerve injury, resulting in the drainage of only small volumes of gas outside the superficial fascia. Even if the superficial fascia has been punctured and gas can be effectively expelled for a short while, the superficial fascia contraction will cause the puncture site to rapidly close, and subsequently, gas cannot be effectively drained.

In the single incision drainage strip method, although the drainage strip can enter the sub-superficial fascial space, the position of drainage strip cannot be easily fixed. Thus, it tends to slip out into the anatomical layers beyond the superficial fascia when the forceps are withdrawn, leading to ineffective drainage.

We used curved forceps for blunt dissection to create a drainage tunnel, which had a clear anatomical level and precise location, thus preventing damage to the trachea and veins. The drainage strip passed through a longer route accurately inside the pre-tracheal space to connect the pneumomediastinal space with the skin incision for sufficient drainage. The significant differences in arterial partial pressure of oxygen and partial pressure of carbon dioxide in the 12th hour of mechanical ventilation between the two groups suggest that the surgery could relieve the pressure of tension pneumomediastinum on the airway, heart, and lungs, improve blood circulation, promote the diffusion and mutual exchange of carbon dioxide and oxygen, leading to the significant difference in total length of mechanical ventilation between the two groups. The two ends of the drainage strip were located outside the skin and were fixed, which facilitates observation. The treatment duration was shortened due to high efficiency of the operation. Nevertheless, this procedure raised the risk of infection and skin scarring.

This study aims to provide a standard and effective drainage method for tension pneumomediastinum occurring from various causes, as well as to provide a reference for the treatment of tension pneumomediastinum caused by COVID-19. Clinicians should carefully consider the following points before selecting this method: familiarity with the local anatomical structure of the pre-tracheal region, as failure to accurately enter the pre-tracheal space will lead to ineffective operation; the method has the risks of damaging the trachea and increasing the infection routes.

Respiratory function improvements could not be completely attributed to drainage of the tension pneumomediastinum, as the treatment of primary diseases such as pneumonia and respiratory distress syndrome also resulted in gas absorption. The contribution of drainage could not be accurately determined since the sample size was too small and additional control groups were lacking, affecting the accuracy of the conclusion.

Conclusions

Our method for draining tension pneumomediastinum improved respiratory function and shortened mechanical ventilation duration. However, further studies are required to confirm these findings.

Declarations

Author contributions:

QLL made the conception and design of the study, performed the operations, drafted the manuscript, and made data analysis and interpretation. CH and SW gave administrative support. All authors collected all data independently and checked the data against each other. All authors contributed to the critical revision of the manuscript, and approved its final form.

Ethical statement:

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The trial was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Guangdong Women and Children Hospital Medical Ethics Committee (No. 202001190) and informed consent was taken from all individual participants.

Competing Interests Statement:

The authors declare that they have no conflicts of interest.

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Figures

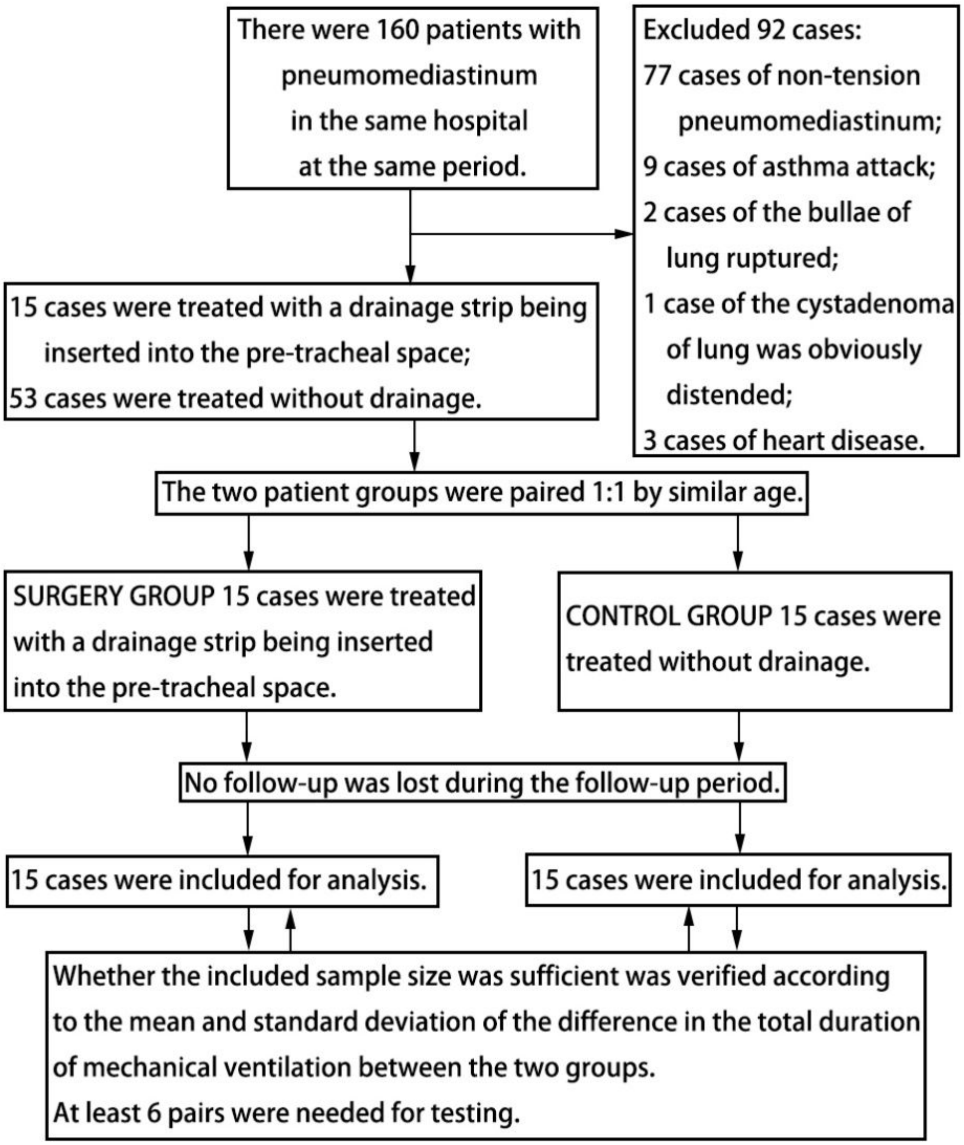

Figure 1

Flowchart of this study

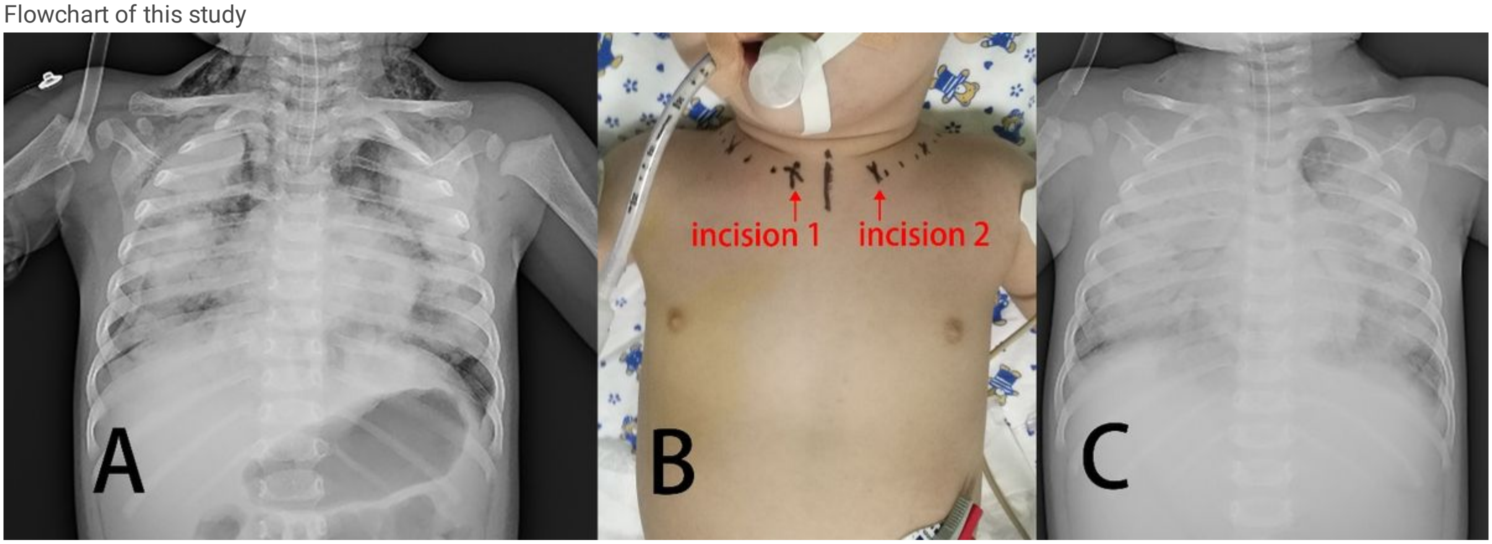

Figure 2

A. Digital Radiography of pre-operation; B. Markers of incisions; C. Digital Radiography after 12 hours of mechanical ventilation

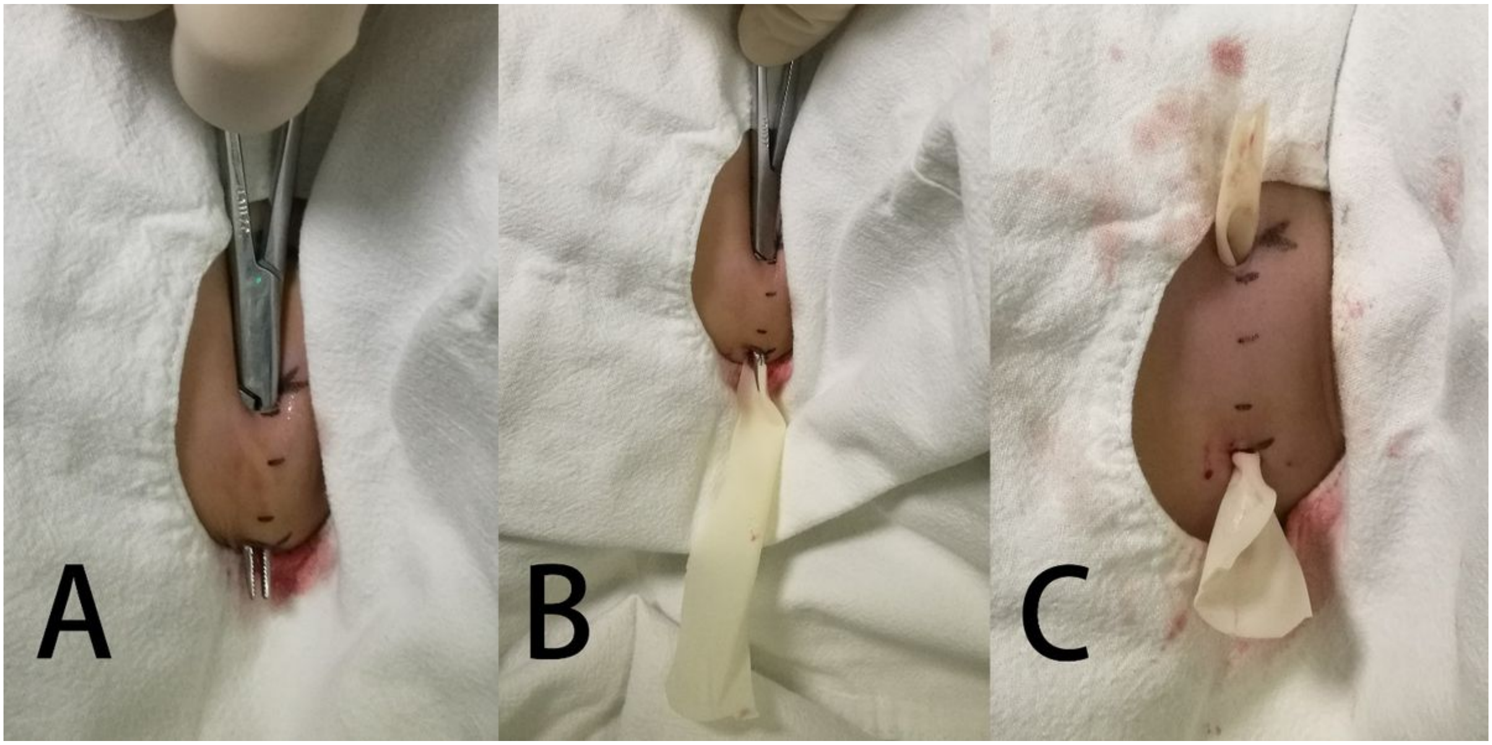

Figure 3

Operational process