What is the best way to secure a chest drain? A scoping review.

Journal:	*Journal of the Intensive Care Society*
Manuscript ID	INC-24-0190.R2
Manuscript Type:	Original Article
Date Submitted by the Author:	22-Apr-2025
Complete List of Authors:	Wong, Chit; Nottingham University Hospitals NHS Trust, Intensive Care Medicine Wright, Joshua; Nottingham Trent University, Medical Engineering Design Research Group Siena, Francesco; Nottingham Trent University, Product Design Department & Medical Engineering Design Research Group Breedon, Philip; Nottingham Trent University, Engineering Department & Medical Engineering Design Research Group Hewson, David; University of Nottingham; Nottingham University Hospitals NHS Trust Beed, Martin; Nottingham University Hospitals NHS Trust, Intensive Care Medicine; University of Nottingham
Keywords:	Thoracostomy, Sutures, Fixation devices, surgical, Occlusive dressings, Intercostal drain
Abstract:	Each year, around 30,000 intercostal chest drains (ICDs) are inserted in the UK, with complications like displacement being a common concern. Various fixation techniques have been proposed to secure ICDs, but there is no consensus on a gold standard. A scoping review was conducted to identify publications describing ICD fixation methods and frequency with which they become dislodged. Three databases were reviewed: MEDLINE from 1946 to 17th October 2024 through the Ovid® website portal, PubMed®, and the Cochrane Central Register of Controlled Trials (CENTRAL). Appropriate search terms and synonyms were applied with Boolean operators and from 5275 identified records 63 were included for review. Nine ICD fixation principles were identified to classify fixation methods: kinking; Poisson-effect ("Roman Sandal"); suture "through" the tube; tube fixation points (cuffs or wings); friction/adhesion (from ties or dressings); external coiling/locking/flattening; internal balloons; internal coiling (pigtails); subcutaneous tunnelling. Many fixation methods combined more than one principle. Although no definitive conclusions on the best fixation method can be drawn from this review, trends suggest that incorporating sutures or using combined techniques, such as sutures paired with dressings, cable ties or balloon catheters, may enhance ICD security. In laboratory conditions, the highest pull force was associated with the modified Jo'berg knot. Further robust studies are needed to compare the effectiveness of different fixation methods superior in terms of displacement rate, but also taking into account pain, skin integrity, wound leakage/infection, or ease of use.

Introduction

A working, well-positioned, intercostal chest drain (ICD) can be precious, particularly in mechanically ventilated, intensive care unit (ICU) patients. ICDs are used to allow drainage of air, blood, pus, or effusion fluid from the pleural space, and they are commonplace in the ICU in the management of trauma, infection and after surgery. Estimates of how often ICDs become partially or completely dislodged vary between 6 and 42 percent and is reported to increase in ICDs *in situ* for greater than twenty-four hours.[1-5] ICD dislodgement may result in additional radiological investigations and exposure, need for nursing and medical review, re-positioning or re-insertion. As an estimated 30,000 ICDs are inserted every year in the UK, preventing dislodgement is an important consideration.[6,7]

Furthermore, ICD insertion is associated with significant risk of complications, including misplacement and visceral damage, making them the subject of alerts and guidelines.[8,9] Minimising the need for re-insertion has obvious safety implications, as well as being economically advantageous and kinder to the patient.

Many different techniques of ICD fixation have been described but there is no agreed gold standard, and it is unclear if any specific fixation technique is superior at reducing the risk of displacement. Many descriptions of fixation techniques are brief and ambiguous.[7,8,10,11] Advanced Trauma Life Support® course (ATLS®) and British Thoracic Society (BTS) guidelines both recommend using sutures, but do not recommend a method of suturing.[7,12]

The aim of this work is to identify the range of published ICD fixation techniques and evaluate whether any have been demonstrated to be more secure.

Methods

We performed a structured search of MEDLINE, PubMed® and the Cochrane Central Register of Controlled Trials (CENTRAL) from 1946 to 17th October 2024 seeking publications describing fixation techniques or a comparison of the frequency of complications associated with different methods of fixation. Controlled trials (whether randomized or not), observational studies, laboratory studies, editorials, and items of correspondence were all considered for inclusion.

The search was performed and reported according to principles outlined by the Joanna Briggs Institute and the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guideline.[13] The aims and methodology were agreed *a priori* but not pre-published in the international prospective register of systematic reviews (PROSPERO) which does not accept scoping reviews. In keeping with similar reviews, ethical approval was deemed unnecessary.

English language articles referring to temporary drains placed transcutaneously into the pleural cavity in either adult or paediatric practice were considered, including those placed using Seldinger or blunt dissection techniques, and those placed during surgery. All designs and sizes of ICD were included, and for the purposes of this review, any reference to "small bore" drains was interpreted as a drain size of less than 18 Fr (French gauge) which has a 6mm outer diameter. Laboratory studies, including live animal, cadaveric, or simulation models, were included if deemed relevant to human practice.

Studies describing drainage systems connecting two body cavities, methods of wound closure rather than drain fixation, or long-term (or outpatient) ICDs were excluded.

The following search terms were used with the appropriate Boolean operators and wildcards to identify articles relating to ICDs: “thoracostomy”, “intercostal”, “pleural”, “chest”; “Seldinger”, “surgical”, “Wayne”, “Fuhrman”, “pigtail”; “tube”, “drain”, “catheter”.

Terms (including wildcards) used to identify different fixation techniques (when combined with the above terms) were: “fixation”, “securement”, “anchor”, “suture”, “stitch”, “adhesive”, “dressing”, “balloon”, “cuff”, “pigtail”.

After de-duplication, titles and abstracts of returned articles were independently screened by two investigators (MB and CW) according to the above *a priori* eligibility criteria. Where the inclusion of an articles was not clear, it was reviewed and discussed jointly by MB and CW to arrive at a consensus decision. This was required where articles only partially fulfilled the inclusion criteria, for example those that used Foley catheters as chest drains.

For studies deemed eligible for inclusion, the following data were extracted: authors, publication date, journal, title, country of origin, fixation technique, type and frequency of complications (where described), population and clinical setting.

Results

A total of 4,531 records were identified by database searching and underwent title and abstract screening, with 159 articles selected for full-text review and 63 included in the final analysis (Figure 1). Of these, 30 were descriptions of techniques with no associated analysis.[14-43] There were 33 studies which examined or compared the efficacy of fixation techniques,[2,3,44-74] including 10 laboratory studies, including both simulations and alive and

cadaveric animal models[44-53]; and 23 human clinical studies[2,3,54-74], of which five involved children.[65-67,69,73]

Fixation techniques

Thirty articles described one or more ICD fixation techniques (Table 1).[14-43] From these articles, nine common principles were identified as a means of classifying methods used to secure ICDs: kinking; Poisson-effect (“Roman Sandal"); suture “through” the tube; tube fixation points (cuffs or wings); friction/adhesion (from ties or dressings); external coiling/locking/flattening; internal balloons; internal coiling (pigtails); subcutaneous tunnelling (Table 2). Several ICD fixation techniques combined several of these principles, and some articles reported using equipment designed for other purposes, such as cable ties and urinary catheters, for ICD fixation.[18,31,47,60]

Laboratory studies

Table 3 summarises laboratory and simulation-based studies of ICD fixation techniques.[47-54] There was no standardised assessment of the efficacy of different techniques. Some studies compared the absolute risk of displacement, while others measured the length of tubing displaced by force, or the time until complete displacement. Experimental methods involved either a continuously increasing force, repeated pulling events using a predetermined force, or subjective estimates of force. Different fixation techniques withstood peak pull forces (i.e. the force required to dislodge an ICD) ranging from 19–180N (Table 4). For comparison, a previous ergonomics paper has suggested that the average peak pull strength of a sample of young men in a standing position was approximately 150N.[75]

Suturing techniques appeared to withstand the highest forces, with the modified “Jo’burg” technique being highly resistant to displacement, resisting forces up to 180N

(Newtons).[51] The modified "Jo'burg" technique is a hybrid technique that combines elements of both pinching and Poisson effects (Figure 12).

Although commonly used suturing techniques that rely on the Poisson-effect ("Roman Sandal") appeared to perform well in laboratory studies, some studies suggested that it was prone to becoming loose with the wrappings slipping down the tube.[49,51] Heskin et al found that the Poisson-effect was made more effective by the addition of cable ties or adhesive dressings to prevent slippage.[47] Combination techniques performed favourably in some studies, however the only force measurements were those from Ringel et al involving cable tie and suture combination – these performed well (approximately 100-150N), although not as well as the modified "Jo'burg" knot.[51] Adhesive dressings did not perform as well in laboratory studies with displacement forces ranging from 19-68N.[45,48,51]

Studies in humans

There were 23 studies that identified that examined ICD fixation in humans (Table 5).[2,3,54-74] Four studies described combined techniques of wound closure and drain fixation in patients undergoing thoracoscopic surgery.[54,56,59,71] They were among several studies addressing skin discomfort or injury/healing as the outcomes of primary interest.[57,58,60,62,74]

A total of 13 studies ivolved pigtail ICDs.[3,55,61-69,72,73] Five such studies were conducted on children (where body size often necessitates small diameter ICDs and where external methods of skin fixation other than dressings are challenging). [65-67,69,73] Mortman et al, one of the largest retrospective studies, indicated a significantly higher incidence of displacement with pigtail drains compared with surgical ICDs.[64] *Double* pigtail drains may have a lower displacement rate compared with standard pigtails.[55]

Mercer et al investigated a custom-made ICD with an integral balloon and identified a lower incidence of drain displacement compared with standard 12Fr ICDs, but also a minor

increase in adverse events including difficult or painful removal.[2] Two further studies also compared how well balloons secured tubes, but these involved the use of Foley urinary catheters as ICDs, a practice that would be considered *off-label* usage in many countries.[18,60]

Discussion

In this scoping review we classified ICD fixation systems using nine principles and have reported a wide variety of laboratory and human studies assessing the comparative performance of fixation techniques that employ those principles. Unfortunately, between-study methodologic and reporting heterogeneity means definitive conclusions on the superiority of any one fixation technique cannot be offered. The type and size of the ICD tube, the suture material and size, the use of any dressings, and the experience of the health practitioner are also likely to play a part.[49,51,52] Given the paucity of definitive evidence, it is perhaps unsurprising that ATLS® and BTS guidelines, arguably the most relevant, do not advocate any specific fixation technique.[3,12]

The literature does, however, allow some conclusions to be drawn. Porcine cadaveric research suggests that the modified "Jo'burg" technique is very resistant to displacement, resisting forces up to 180N.[51] Our review also suggests that combining different methods of securement, for example combining adhesive dressing with sutures, or suturing pigtail, small bore Seldinger, and balloon drains, may be more successful at preventing dislodgement than single techniques alone.[2,3,47] In fact, BTS guidelines recommend that small bore or pigtail ICDs are sutured alongside any other fixation method, based in part on the results of Asciak et al.[3,7]

Another BTS recommendation is that any adhesive dressings should involve a "mesentery" or "omental tag" (see figure 8).[10] The paper by Domanska et al would seem to

cast doubt on this suggestion as it found that a higher force was required to dislodge a drain with a "bridge" covering (see Figure 7) than those with a mesentery.[45] However, insofar as comparison between studies is possible, our scoping review finds that that adhesive dressings appear less effective than sutures in preventing ICD dislodgement (Table 4).

Some fixation techniques may have limited applicability. Although a large proportion of included studies involve pigtail drains, their use remains contentious for several indications.[64] Another example, tunnelling, is typically only feasible for large bore drains inserted during surgical wound closure. In contrast, certain techniques may provide added benefits in specific circumstances. For example, balloon-tipped urinary catheters have been deliberately used to tamponade bleeding intercostal vessels.[76] Some intraoperative techniques combine chest drain fixation with wound closure aiming for improved cosmetic results.

The re-purposing of medical equipment as ICDs, including central venous, Bonnano, and urinary catheters, was described in several papers that were excluded at the screening stage. Off-label use of equipment not designed for chest drainage is discouraged as it leaves health organisations and professionals liable in the event of adverse reactions.[77] In spite of this, we chose to include two references to Foley catheters in our review due to the size of the cohorts examined, and the potential requirement for non-standard approaches to ICDs in low-resource settings.[18,60]

One of the strengths of this study is that it had very broad search criteria which meant a wide range of methodologies were reviewed. These included living and cadaveric, human and animal models. By way of contrast, a weakness of this study is that it was not possible to synthesise all of the available results into definitive recommendations on fixation technique. Only 15 studies compared frequency of dislodgement, but often this was as a

secondary outcome with methodology that was poorly described and involved small numbers of participants.[2,3,54-56,61,62,66-69,72-74] Another weakness of this study is that it has not been possible to identify the frequency with which different fixation techniques are encountered in the ICU setting or in other clinical scenarios. The largest audit of UK ICDs did not record which techniques were used, only that "accidental dislodgement of chest drains should be avoided by adequate fixation".[4]

We also recognise that bland dislodgement rates are only one aspect of what might make one fixation method better or worse than any other. Consideration of insertion time, expertise required, cost, patient experience (including pain), skin integrity, and wound leakage (including subcutaneous emphysema and wound infection) should all be considered important. Many of these factors were outcome measures in several of the studies we reviewed.[2,60,56-58,61-63,71,74] Future research should combine examinations of the security of different fixation methods with the other outcomes described above.

Conclusions

Despite the recognised problems associated with of ICD fixation failure, research in this field has been sporadic and inconsistent. This review has attempted to summarise existing research to inform current practice and future research needs. Individual expert practitioners with established ICD fixation techniques acceptable to their institution and patients should be reticent to alter practice based solely on this review of the literature. However, we can cautiously suggest that it was possible to identify certain trends. For example, the more secure ICD fixation techniques identified in this scoping review appear to be those involving sutures or sutures combined with cable ties or adhesive dressings. Of the

suture techniques for which evidence was available, those which indented the chest drain were more successful than those that did not, whilst in a laboratory setting the highest identified pull force identified was associated with the modified Jo'berg knot.

References

1. Sundaralingam A, Bedawi EO, Harriss EK, et al. The frequency, risk factors, and management of complications from pleural procedures. *Chest* 2022; 161: 1407–25
2. Mercer RM, Mishra E, Banka R, et al. A randomised controlled trial of intrapleural balloon intercostal chest drains to prevent drain displacement. *Eur Resp J* 2022; 60: 2101753
3. Asciak R, Addala D, Karimjee J, et al. Chest drain fall-out rate according to suturing practices: a retrospective direct comparison. *Respiration* 2018; 96: 48–51
4. Hooper CE, Welham SA, Maskell NA. Pleural procedures and patient safety: a national BTS audit of practice. *Thorax* 2015; 70: 189–91
5. Rahman NM, Pepperell J, Rehal S, et al. Effect of opioids vs nsaids and larger vs smaller chest tube size on pain control and pleurodesis efficacy among patients with malignant pleural effusion: the time1 randomized clinical trial. *JAMA* 2015; 314: 2641
6. Evans JM, Ray A, Dale M, et al. Thopaz+ portable digital system for managing chest drains: a nice medical technology guidance. *Appl Health Econ Health Policy* 2019; 17: 285–94
7. Asciak R, Bedawi EO, Bhatnagar R, et al. British Thoracic Society clinical statement on pleural procedures. *Thorax* 2023; 78: s43–68
8. Akram AR, Hartung TK. Intercostal chest drains: a wake-up call from the National Patient Safety Agency rapid response report. *J Royal College of Physicians Edinburgh* 2009; 39: 117–20

9. National Patient Safety Agency. Rapid response report: risks of chest drain insertion. NPSA 2008; RRR003.
10. Laws D, Neville E, Duffy J. BTS guidelines for the insertion of a chest drain. *Thorax* 2003; 58: ii53
11. Anderson D, Chen SA, Godoy LA, et al. Comprehensive review of chest tube management: a review. *JAMA Sur*g 2022; 157: 269-74
12. Advanced Trauma Life Support Student Course Manual 10th Ed. American College of Surgeons, 2018.
13. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018; 169: 467–73
14. Anonymous. Dressing up for a change: chest tube insertion site. Nursing 1996; 26: 44–6
15. Akuetteh PDP, Akuetteh YB, Shen X, et al. A novel silicone fixation dressing: a possibly ideal method for drainage tube fixation. *Surg Innov* 2020; 27: 644–6
16. Bar-Maor JA. A simple technique for anchoring tubes to the skin. *J Trauma* 1994; 36: 112
17. Barnung S, Steinmetz J. A prehospital use of ITClamp for haemostatic control and fixation of a chest tube: prehospital use of ITClamp. *Acta Anaesthesiol Scand* 2014; 58: 251–3
18. Ben-Nun A, Best LA. A simple method of using a foley catheter to drain pleural effusion. *Surg Today* 2008; 38: 769–70
19. Boyle A. Securing intercostal drains. *J Accident Emerg Med*; 1999; 16: 239
20. Carignan M, Nelson L. Surgical drainage devices. Improved securement = improved outcomes. *Can Oper Room Nurs J* 2000; 18: 18–9

21. Frank M. A simple technique for securing tubes. *Ann Emerg Med*; 1983; 12: 25–7

22. Fuhrman BP, Landrum BG, Ferrara TB, et al. Pleural drainage using modified pigtail catheters. *Crit Care Med* 1986; 14: 575–6

23. Inzirillo F, Giorgetta C, Ravalli E, et al. “Roman Sandal” modified method for securing the chest drain to the skin. *Gen Thorac Cardiovasc Surg* 2013; 61: 171–3

24. Jetty P, Mehran RJ. Inadvertent suture through the chest tube: a simple solution to a frustrating problem. *Annals Thorac Surg*; 2000; 69: 261–2

25. Jung AL, Nelson J, Jenkins MB, et al. Clinical evaluation of a new chest tube used in neonates. *Clin Pediatr* 1991; 30: 85–7

26. Kamiyoshihara M, Ibe T. A new painless method of fixation and removal of a silicone chest drain after thoracic surgery. *Surg Today* 2008; 38: 283–4

27. Kao C-N, Chang C-W, Hsieh M-C, et al. Pre-embedding subcutaneous suture for chest-tube insertion in uniportal video-assisted thoracoscopic surgery. *J Thorac Dis* 2017; 9: E938–40

28. Kesavan S, Angelini GD. Securing an intercostal chest drain without sutures. *Thorax* 2011; 66: A79

29. Lawless S, Orr R, Killian A, et al. New pigtail catheter for pleural drainage in pediatric patients. *Crit Care Med*; 1989; 17: 173–5

30. Maritz D, McLauchlan C. A novel way to secure a chest drain. *Ann R Coll Surg Engl* 2014; 96: 82

31. Melamed E, Blumenfeld A, Lin G. Locking plastic tie—a simple technique for securing a chest tube. *Prehosp Disaster Med* 2007; 22: 344–5

32. Plani F. Securing intercostal drains in trauma surgical practice – how I do it. *CME* 2004; 22: 388–90

33. Perez CR, Romitti MG, Pezzotti E, et al. Subcutaneously anchored sutureless device for securement of chest tubes in neonates with pleural effusion: three case reports. *Case Rep Pediatr* 2020; 2020: 1–5

34. Rashid M, Wikstrom T, Ortenwall P. A simple technique for anchoring chest tubes. *Eur Respir J* 1998; 12: 958–9

35. Seaman JB. Bow mattress suture for chest catheters. *J Thorac Cardiovasc Surg* 1959; 38: 277–8

36. Simon RR, Bailey Jr TD, Abraham E, et al. A new technique for securing a chest tube. *Ann Emerg Med*; 1982; 11: 619–21

37. Son BS, Park JM, Seok JP, et al. Modified incision and closure techniques for single-incision thoracoscopic lobectomy. *Ann Thorac Surg* 2015; 99: 349–51

38. Spinoza M, McQuillan A, Elliott M. A simple, novel, cost-effective technique for the management of chest drains. *Ann R Coll Surg Engl* 2010; 92: 713–4

39. Sun Z, Zheng J, Cao Z, et al. An improved method of anchoring chest drain and suture technique for uni-portal VATS incision. *Gen Thorac Cardiovasc Surg* 2021; 69: 1515–8

40. Tinckler LF. Self-retaining chest drainage tubes. *Br J Surg* 1976; 63: 141–2

41. Weber MD, Sparks JD. Use of a catheter-securement device in pediatric patients with decreased skin integrity. *J Wound Ostomy Continence Nurs* 2005; 32: 269–70

42. Yang MX, Ault MJ. A punctureless and secure method of chest tube fixation. *Ann Emerg Med* 2018; 72: 106–7

43. Zhang X, Li W, Li Z, et al. Anchoring chest drains with an elegant sailor's tying technique. *Surg Innov* 2016; 23: 328–30

44. Ablett DJ, Navaratne L, Chua D, et al. The modified 'Jo'burg' technique for securing intercostal chest drains. *J R Army Med Corps* 2017; 163: 319–23

45. Domanska K, O'Sullivan A, Mulcahy N, et al. Tape it up: scientific experiment testing the best taping method for intercostal chest drains. *Emerg Med J* 2023; 40: 726–7

46. Eisenkraft A, Gavish L, Wagnert-Avraham L, et al. Novel self-fixation chest drain device tested in a swine model of pneumo-hemothorax. *Minim Invasive Ther Allied Technol* 2021; 30: 40–6

47. Heskin L, Cahill V, Filobbos G, et al. A new adaptation for a secure surgical drain placement and a comparison with four common drain fixation methods. *Ann R Coll Surg Engl* 2019; 101: 60–8

48. Homma T, Ojima T, Shimada Y, et al. Use of Quickfix for tape fixation of chest tubes: a multi-center doctor-nurse questionnaire survey and fixing strength comparison study. *J Thorac Dis* 2020; 12: 493–503

49. Howes RJ, Calder A, Hollingsworth A, et al. The end for the 'Roman Sandal': an observational study of methods of securing chest drains in a deployed military setting. *J R Nav Med Serv* 2015; 101:42-6

50. Mckee J, Mckee I, Bouclin M, et al. Use of the iTClamp versus standard suturing techniques for securing chest tubes: A randomized controlled cadaver study. *Turk J Emerg Med* 2018; 18: 15–9

51. Ringel Y, Haberfeld O, Kremer R, et al. Intercostal chest drain fixation strength: comparison of techniques and sutures. *BMJ Mil Health* 2021; 167: 248–50

52. Song EK, Mann FA, □□ CC. Comparison of different tube materials and use of chinese finger trap or four friction suture technique for securing gastrostomy, jejunostomy, and thoracostomy tubes in dogs. *Vet Surg* 2008; 37: 212–21

53. Tokur M, □□ M, □□ M, et al. An experimental comparative study on classic tube thoracostomy and thoracostomy with a newly designed thorax drainage catheter. *Turk J Med Sci* 2016; 46: 91–6

54. Chen Z, Xin N, Huang K, et al. A new traceless technique for cosmetic closure of minimally invasive incision and chest tube fixation after uniportal video-assisted thoracoscopic surgery. *Front Surg* 2022; 9: 874983

55. Cho Y, Lee HN, Shin JH, et al. Double-pigtail drainage catheter: a new design for efficient pleural drainage. *Medicina* 2023; 59: 1089

56. Fu R, Zhang J, Dong S, et al. Drainage tube hole suture improvement: □□ stitches. *Thorac Cancer* 2019; 10: 1827–33

57. Gross SL, Jennings CD, Clark RC. Comparison of three practices for dressing chest tube insertion sites: a randomized controlled trial. *MedSurg Nursing* 2016; 25: 229–33

58. Jones S. A randomized comparative effectiveness study comparing two chest tube dressing methods. *Crit Care Med* 2013; 41: A96–7

59. Kim KS. Barbed suture material technique for wound closure and concomitant tube placement in uniportal VATS for pneumothorax. *J Thorac Dis* 2017; 9: 1265–72

60. Lai Y, Wang X, Zhou H, et al. Is it safe and practical to use a Foley catheter as a chest tube for lung cancer patients after lobectomy? A prospective cohort study with 441 cases. *Int J Surg* 2018; 56: 215–20

61. Li X, Chen X, He S, et al. The application of pigtail catheters in postoperative drainage of lung cancer. *Clin Lung Cancer* 2022; 23: e196–202

62. Mehta AA, Gupta AS, Mohamed AKS. The pigtail catheter for pleural drainage: a less invasive alternative to tube thoracostomy. *J Curr Surg* 2016; 6: 52–6

63. Miotto A, Honda PAA, Dias DCA, et al. Early discharge for patients with benign pleural effusions using a Wayne catheter (pigtail) chest drain - analysis of safety, complications, and quality of life. *Rev Col Bras Cir* 2022; 49: e20213139

64. Mortman KD, Tanenbaum MT, Cavallo KM, et al. Reintervention rate after pigtail catheter insertion compared to surgical chest tubes. *Am Surg* 2023; 89: 5487–91

65. Panza R, Prontera G, Ives KN, et al. Pigtail catheters versus traditional chest drains for pneumothorax treatment in two NICUs. *Eur J Pediatr* 2020; 179: 73–9

66. Petel D, Li P, Emil S. Percutaneous pigtail catheter versus tube thoracostomy for pediatric empyema: A comparison of outcomes. *Surgery* 2013; 154: 655–61

67. Pierrepoint M, Evans A, Morris S, et al. Pigtail catheter drain in the treatment of empyema thoracis. *Arch Dis Child* 2002; 87: 331

68. Rasihashemi SA, Ramouz A, Amini H. Comparison of the therapeutic effects of a pigtail catheter and chest tube in the treatment of spontaneous pneumothorax: a randomized clinical trial study. *Turk Thorac J* 2021; 22: 459–65

69. Roberts JS, Bratton SL, Brogan TV. Efficacy and complications of percutaneous pigtail catheters for thoracostomy in pediatric patients. *Chest* 1998; 114: 1116–21

70. Ross S, Ali H, Allsop L, et al. A pilot study of a dedicated ballooned intercostal drain. *Thorax* 2016; 71: A91.2-A92

71. Shi W, Hu Y, Wang C, et al. Experience of a modified chest tube suture-fixation technique in uniportal thoracoscopic pulmonary resection. *BMC Surg* 2023; 23: 73

72. Vaidya S, Karmacharya RM, Shrestha B, et al. Comparative study between the use of pigtail catheters and traditional chest tube drain in cases with pneumothorax. *Kathmandu Univ Med J* 2022; 20: 24–8

73. Wei Y-H, Lee C-H, Cheng H-N, et al. Pigtail catheters versus traditional chest tubes for pneumothoraces in premature infants treated in a neonatal intensive care unit. *Pediatr Neonatol* 2014; 55: 376–80

74. Wood MD, Powers J, Rechter JL. Comparative evaluation of chest tube insertion site dressings: a randomized controlled trial. *Am J Crit Care* 2019; 28: 415–23

75. Das B, Wang Y. Isometric pull-push strengths in workspace: 1. Strength profiles. *Int J Occup Saf Ergon* 2004; 10: 43–58

76. Chao BF, Jian YJ, Hao HZ, et al. Balloon Foley catheter compression as a treatment for intercostal vessel bleeding. *Injury* 2011; 42: 958–9

77. Medicines & Healthcare products Regulatory Agency. Off-label use of a medical device https://www.gov.uk/government/publications/medical-devices-off-label-use/off-label-use-of-a-medical-device (accessed 24/2/2025)

78. Russo M, Di Capua J, Anlage A, et al. Preventing inadvertent drain removal using a novel catheter securement device. *Sci Rep* 2023; 13: 16130

Authors' contributions

Study design, planning, conduct: CW, MB, DWH. Writing, and revision of manuscript: all authors.

Declaration of interest

MB receives an annual honorarium for work with Quotient Sciences.

The other authors have no interests to declare.

Funding

This study/project is funded by the NIHR - i4i Product Development Awards (PDA) - Breakaway Chest Drain Valve (Reference: NIHR204562). The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

Table 1. Published descriptions of one or more novel techniques for intercostal chest drain fixation.

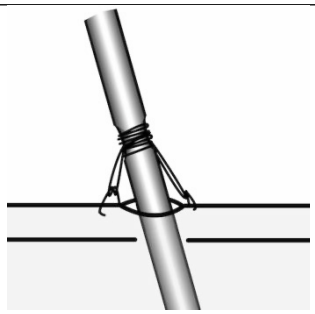
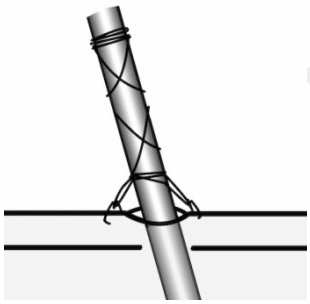
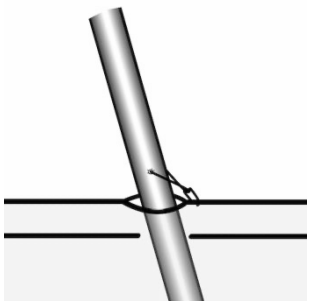
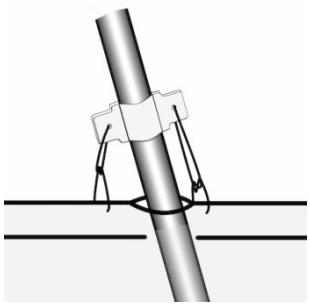
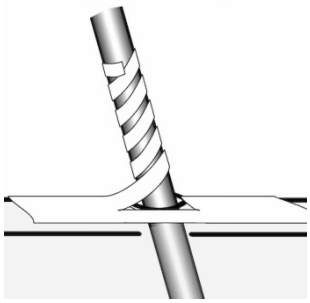
Authors	Year	Country of Origin	Fixation technique	Relevant comments	Population
Anonymous[14]	1996	Unclear	Adhesive dressing around drain and over skin with occlusive petroleum gauze followed by pre-slit sterile gauze and tape creating an air-tight seal	Generic adhesive bandages and dressings – not specific for drains	Trauma, surgery or spontaneous pneumothorax
Akuetteh PDP et al.[15]	2020	China	Applying a two-way wrapping technique to the re-stickable silicone adhesive dressing with an absorption pad	Dressing designed for drains	Thoracic surgical patients
Bar-Maor J.[16]	1994	USA	Sutures to skin followed by suture around ICD under tension		Trauma
Barnung S et al.[17]	2014	Denmark	Clamp to device and skin	iTClamp™ is a temporary wound closure device	Prehospital trauma
Ben-Nun A.[18]	2008	Israel	Intrapleural balloon Suture to skin and drain +/- Hemlich valve	Foley urinary catheter used	Patients with pleural effusion (general and thoracic surgical patients)
Boyle A.[19]	1999	UK	External cuff on drain Suture to skin and around cuff	Cuff fashioned from tubing	Trauma
Carignan M et al.[20]	2000	Canada	Catheter-securement device	Statlock™ dressing	No specific setting
Frank M.[21]	1983	USA	Sutures to skin and around the ICD in opposite direction leaving indentation		No specific setting
Fuhrman BP et al.[22]	1986	USA	Modified pigtail inserted with modified Seldinger technique. Luer-locked to a negative pressure, closed pleural drainage system	Demonstrated in children and neonates	Infants and children with pleural effusion/ pleural collection of hyperalimentation fluid/ pneumothoraces
Inzirillo F et al.[23]	2012	Italy	Alpha-shaped sutures around the wound Same sutures used to cross around the ICD in a Roman Sandal fit	Single suture for tube fixation and drain hole closure	Thoracic surgical patients
Jetty P et al.[24]	2000	Canada	Sutures to skin and *through* drain		Thoracic surgical patients (pneumonectomy)

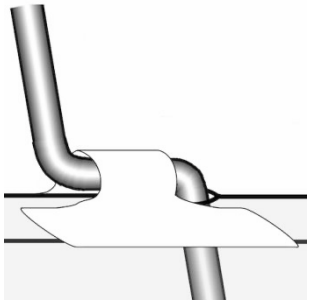
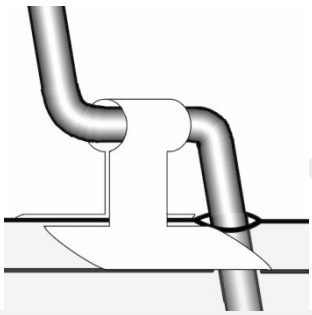
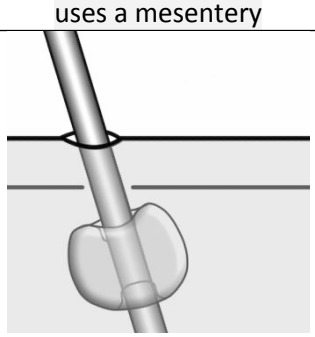
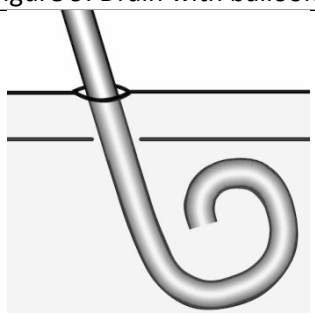
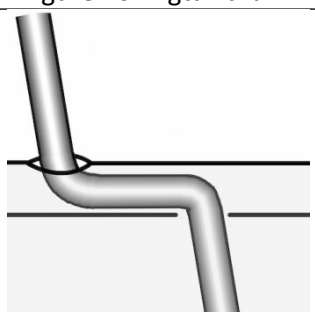
Jung AL et al.[25]	1991	USA	"Unique" pigtail design	Unable to access all of article	Neonates with pneumothoraces
Kamiyoshihara M et al.[26]	2008	Japan	Tunnelling, stapler and dressing	Tunnel made during thoracoscopy	Thoracic surgical patients
Kao CN et al.[27]	2017	Taiwan	Three pre-embedded continuous subcuticular sutures applied to wound leaving an opening for ICD insertion before tightening post insertion	Combined thoracoscopy wound closure and drain fixation	Thoracic surgical patients (uniportal VATS)
Kesavan S et al.[28]	2011	UK	Intrapleural balloon and external balloon		Paediatric patients with pneumothoraces
Lawless S et al.[29]	1989	USA	Modified pigtail inserted with Seldinger technique. Christmas tree adaptor is used to connect the catheter and the drainage system	May be the same as Fuhrman et al as Fuhrman is co-author[23]	Neonates and children with pneumothorax or pneumomediastinum during mechanical ventilation
Maritz D et al.[30]	2014	UK	Horizontal mattress sutures placed with a simple knot placed distally halfway along the free ends. Wrap the thread around the ICD the same way up to the knot level. Pass the free ends through the loop of the horizontal mattress suture. Pull and wrap the free ends around the ICD in opposite direction before placing another knot for securement.	Description of the "Jo'burg knot"	No specific setting
Melamed E et al.[31]	2007	Israel	Locking cable tie around tube; suture to skin and cable tie		Prehospital trauma
Plani F.[32]	2004	South Africa	Vertical mattress suture placed to skin as the anchoring suture. A first throw of the suture is placed while a knot is tied 15 cm from the wound edge. ICD is wrapped around by the suture until the knot level before the knot is passed underneath the suture loop. The ends are then again tied around the ICD. Additional vertical mattress sutures could be placed on the sides for extra security.	Description of the "Jo'burg knot"	No specific setting
Perez CR et al.[33]	2020	Italy	Catheter-securement device and cyanoacrylate glue and dressing	SecurAcath™ central venous access securement device	Premature neonates with pleural effusion

Rashid MA et al.[34]	1998	Sweden	Two stitches placed on either side of wound with the free edges secured around the ICD. One horizontal mattress stitch placed in the middle of the wound wrapping several times around the ICD.	Combined wound closure and drain fixation	Patients requiring closed tube thoracostomy
Seaman JB.[35]	1959	USA	Horizontal mattress sutures to skin and loop around the ICD. Friction knot and double bow knot then tied. Narrow adhesive tape is placed in a spiral fashion over the suture onto the ICD.		Patients requiring a chest catheter
Simon RR et al.[36]	1982	USA	Modified horizontal mattress stitch applied to skin and wrapped around ICD		Patients underwent closed tube thoracostomy
Son BS et al.[37]	2015	South Korea	Subcutaneous suture and knot are placed. An anchor suture is then placed through the knot and fixating the ICD wrapping around it.		Thoracic surgical patients (single incision VATS lobectomy)
Spinoza M et al.[38]	2010	UK	Braided sleeve with anchoring points for suturing		No specific setting
Sun Z et al.[39]	2021	China	Sutures to muscles on both sides of incision and tie a knot around ICD. A subcutaneous suture is placed continuously from the front side to the backside.		Thoracic surgical patients (uniportal VATS patients)
Tinckler LF.[40]	1976	UK	Intrapleural balloon and movable external collar		No specific setting
Weber MD et al.[41]	2005	USA	Adhesive dressing to skin and sutures to drain	Statlock™ dressing – for newer versions sutures not required	Infant with chylothorax
Yang MX et al.[42]	2018	USA	Adhesive dressing to skin with additional sutures to drain	Statlock™ urinary catheter dressing	No specific setting
Zhang X.[43]	2016	China	Sutures to skin and sailor's knot around the ICD. Additional surgical knots are used to lock the sailor's knot		Thoracic surgical patients

Abbreviations: Intercostal chest drain (ICD); United Kingdom (UK); United States of America (USA); video-assisted thoracoscopic surgery (VATS)

Table 2. Classification system of intercostal chest drain fixation principles. Different techniques may combine more than one principle.

Pictorial representation	Description	Attachment to skin*	Notes
 Figure 2. Kinking with a suture.	Pinching Indenting or pinching of the drain. Most commonly achieved with sutures, but also described with cable ties and also specially designed clamps.	Sutures. Clamps pinching skin described in emergency settings.	Difficulty in kinking thinner drains. Possible to occlude smaller drains.
 Figure 3. Roman Sandal.	Poisson effect Relies on material wrapped around drain narrowing when put under tension. Most commonly achieved with "Roman Sandal" type suture. Specially designed "Chinese finger trap" also available.	Sutures,	Becomes ineffective if becomes slack and "falls" towards the wound.
 Figure 4. Suture through drain.	Suture *through* drain	Suture	Breaks integrity of the drain. Difficult to do in smaller or thicker drains.
 Figure 5. Drain with wings.	"Winged" tubes Some specially designed small bore tubes have attachments through which sutures can be passed. Adhesive dressing "flags" can be stuck to the drain for a similar effect	Suture	
 Figure 6. Adhesive tape.	Friction / adhesion Most commonly suture or adhesive dressing.	Sutures or adhesive dressing	Loosely applied sutures that do not kink the tube

 Figure 7. External flattening using a dressing or tape (a "bridge").  Figure 8. Dressing or tape with uses a mesentery	External coiling, locking, or flattening. Small bore tubes can be laid flat against skin and stuck to the chest wall with adhesive dressings. The same effect can be achieved with a specially designed "capstan" or button that the tube can be wrapped around and locked into.[78]	Adhesive dressing. (Sutures if a locking button is used or if the drain is sutured to the skin at multiple sites).[78]	More commonly used for small bore or flexible tubes. Dressings or tape can be applied using different techniques, ranging from a simple covering (a "bridge") to a "mesentery" or a wraparound.[45]
 Figure 9. Drain with balloon.	Internal balloon** Specially designed ballooned drains exits where the inflated balloon resists drain displacement. Alternative designs exist with additional with external cuffs or balloons.	N/A	Urinary catheters have been used. These only have a small amount of drainage tube extruded past the balloon.
 Figure 10. Pigtail drain.	Internal coiling (pigtail) Drain is designed to coil after trocar is removed or after internal coiling suture is pulled. Double-pigtail drains also exist.	N/A	Only available for small bore drains such as Wayne or Fuhrman tubes.
 Figure 11. Tunnelled drain.	Tunnelled Skin incision is two or three intercostal spaces above or below entry into the pleura. The drain is tunnelled into subcutaneous tissue in between.	N/A	Difficult with large bore tubes. Most easily performed at thoracrotomy/thoracoscopy. Also used for some small-bore long-term drains.

*In practice combinations of the above principles are used, particularly when fixing the drain to the skin. For example, studies describe securing balloon and pigtail catheters with additional sutures.[2,3]
**One balloon device involves a “port” which penetrates the chest and has a balloon attached. A drain can then be inserted through the port, but it is not clear how the drain is held by the port.[46]

Table 3. Laboratory studies (including animal or simulation models) analysing different types of intercostal chest drain fixation methods.

Authors	Year	Country of Origin	Fixation method	Variety of methods	Details of research	
					Study design	Relevant outcome(s)
Ablett DJ et al.[44]	2017	UK	Sutures to skin and drain.	8	Porcine cadaveric crossover.	Length of ICD dislodged after 50N applied for 10 seconds.
Domanska K et al.[45]	2023	Ireland	Comparison of techniques of tape fixation using "Sleek"® tape.	6	Laboratory model comparative analysis.	Maximum pull force (N) and cycles to failure with repeated 30N pull force.
Eisenkraft A et al.[46]	2021	Israel	Port with intrapleural balloon with external fixation disc through which drains are inserted.	1	Live porcine observational study.	Ease of use; evidence of displacement up to 58.8N traction force.
Heskin L et al.[47]	2018	Ireland	Sutures to skin; sutures to drain +/- cable tie, +/- adhesive dressing.	5	Survey of techniques used (n=138 responses) and laboratory model research comparative analysis.	Repeated cycles of increasing force up to 30N. Number of cycles until failure / displacement in mm.
Homma T et al.[48]	2020	Japan	Dressings to skin and tube.	8	Survey of techniques used and Laboratory model research comparative analysis.	Peak and total resistance force (N) and energy (J).
Howes RJ et al.[49]	2015	UK (military study conducted in Afghanistan)	Sutures to skin; sutures to drain +/- adhesive "flag" dressing.	7	Observational study. Mannikin simulation comparing techniques. Partially blinded assessment.	Time to complete insertion; displacement by "moderate" manual force.
Mckee J et al.[50]	2018	Canada	iTClamp™ vs sutures; both to skin and drain.	2	Human cadaveric comparative analysis.	Insertion time; displacement events after 5lb pull force (22.2N) applied.
Ringel Y et al.[51]	2021	Israel	Sutures, ties, dressings and fixation devices.	14	Porcine cadaveric comparative analysis.	Breaking force and failure point.
Song EK et al.[52]	2008	USA	Sutures to skin and drain.	2	Canine cadaveric comparative analysis.	Force required for failure and displacement; point of failure.
Tokur M et al.[53]	2016	Turkey	Intrapleural balloon with external cuff and lock vs standard drain.	2	Live porcine comparative analysis	Speed of insertion; evidence of iatrogenic insertion injury.

Abbreviations: Intercostal chest drain (ICD); Joules (J); Newtons (N); pounds (lb); United Kingdom (UK); United States of America (USA); millimetres (mm)

Table 4. Comparison of the peak pull forces at which failure occurs with ICD fixation methods.

Material	Technique	Pull force to cause failure (Newtons)	Experimental model	Author
Suture	Purse string	70-88N**	Porcine cadaver	Ringel et al[51]
	Multiple (four) friction sutures	83-103N*	Canine cadaver	Song et al[52]
	Poisson-effect	74-83N* 71-96N**	Porcine and canine cadaver	Song et al[52] Ringel et al[51]
	Modified "Jo'burg" knot	129-180N**	Porcine cadaver	Ringel et al[51]
Suture combined with locking cable tie		93-147N**†	Porcine cadaver	Ringel et al[51]
Port with intrapleural balloon		>58.8N	Porcine/anaesthetised	Eisenkraft et al[46]
Commercially designed Tube holder		20N	Porcine cadaver	Ringel et al[51]
Adhesive dressings		19-68N 25-52N 50N	Polyethylene plate Unclear‡ Porcine cadavers	Homma et al[48] Domanska et al[45] Ringel et al[51]

* Dependent on tube material (silicone > polyvinyl chloride) ** Dependent on suture material (1silk >0silk)

† Dependent on number of passes through locking tie (2>1).

‡ Domanska et al did not use human or animal subjects. It is likely that a laboratory surface of some description was used. Differences in drain material and size, suture material, and dressings may affect the reliability of comparisons.

Table 5. Human clinical studies analysing or comparing different types of intercostal chest drain fixation methods.

Authors	Year	Country of origin	Title	Fixation method	Details of research		
					Type of study	Setting and participants (n)	Relevant outcome(s)
Asciak R et al.[3]	2018	UK	Chest drain fall-out rate according to suturing practices: a retrospective direct comparison	Sutures to skin and drain vs. pigtail drain and dressing	Retrospective cohort case-control study	Respiratory / cardiothoracic wards; (n=369)	No. of displacements Time to displacement
Chen Z et al.[54]	2022	China	A new traceless technique for cosmetic closure of minimally invasive incision and chest tube fixation after uniportal video-assisted thoracoscopic surgery	Sutures to skin and drain	Retrospective cohort case-control study comparing techniques	Following uniportal thoracoscopic surgery; (n=258)	Length of stay; ICD "prolapse"; other complications
Cho Y et al.[55]	2023	Republic of Korea	Double-pigtail drainage catheter: a new design for efficient pleural drainage	Double vs single pigtail; +/- suture	Retrospective observational cohort analysis	Hospital drainage of pleural effusions; (n = 343; 382 procedures)	"Dysfunctional retraction"; blockage
Fu R et al.[56]	2019	China	Drainage tube hole suture improvement: Removal-free stitches	Sutures to skin and drain	Retrospective cohort case-control study of skin port closure and ICD fixation	Following uniportal thoracoscopic surgery; (n=102)	Scarring, hernia, and infection; tube bypassing or "dislocation"
Gross SL et al.[57]	2016	USA	Comparison of three practices for dressing chest tube insertion sites: a randomized controlled trial	Dressings to skin. Unclear if other fixation also used.	Prospective randomized control trial of three different dressings	Cardiothoracic patients (n=59)	Wound leakage; pain scores and skin integrity.

Jones S.[58]	2013	USA	A randomized comparative effectiveness study comparing two chest tube dressing methods	Adhesive dressings. Unclear if other methods used	Randomised observational study	Cardiothoracic surgery (n=79)	Skin irritation and damage
Kim KS.[59]	2017	Republic of Korea	Barbed suture material technique for wound closure and concomitant tube placement in uniportal VATS for pneumothorax	Sutures to skin and drain	Description of technique Non-randomised controlled trial	Following uniportal thoracoscopic surgery. (n = 31; 35 drains)	ICD complications
Lai Y et al.[60]	2018	China	Is it safe and practical to use a Foley catheter as a chest tube for lung cancer patients after lobectomy? A prospective cohort study with 441 cases.	Intrapleural balloon vs chest drain – other fixation not recorded	Prospective non-randomized cohort study	Postoperative thoracoscopic cancer surgery (n=441)	Pain scores and frequency of medical complications
Li X et al.[61]	2021	China	The application of pigtail catheters in postoperative drainage of lung cancer	Pigtail + fixation device/suture vs silicone tubes + suture	Randomized control trial, unblinded	Thoracoscopic surgery patients; (n=1375)	Length of stay; pain; complications including slippage and obstruction
Mehta AA et al.[62]	2016	India	The pigtail catheter for pleural drainage: a less invasive alternative to tube thoracostomy	Pigtail vs standard drain; fixation method unclear	Observational cohort analysis	Hospital drainage of pleural effusions; (n=92)	Pain; length of stay; complications including blockage and accidental removal
Mercer RM et al.[2]	2022	UK	A randomised controlled trial of intrapleural balloon intercostal chest drains to prevent drain displacement	Intrapleural balloon vs standard drain, both +/- suture and dressing	Randomised controlled trial, unblinded	Any hospital environment where small bore drain required. (n=267)	Drain displacement rate, and time to displacement; pain; length of stay; requirement for X-ray; other adverse events

Miotto A et al.[63]	2022	Brazil	Early discharge for patients with benign pleural effusions using a Wayne catheter (pigtail) chest drain - analysis of safety, complications, and quality of life	Pigtail; fixation method unclear	Prospective observational cohort analysis	Outpatient drainage of pleural effusions; (n=47)	Pain; catheter “replacement”
Mortman KD et al.[64]	2023	USA	Reintervention rate after pigtail catheter insertion compared to surgical chest tubes	Pigtail vs standard drain; fixation method unclear	Retrospective observational cohort analysis	Hospital patients requiring pleural drainage; (n=1032)	Length of stay; complications requiring re-intervention
Panza R et al.[65]	2020	UK, Italy	Pigtail catheters versus traditional chest drains for pneumothorax treatment in two NICUs	Fuhrman pigtail; fixation method unclear	Retrospective observational cohort analysis	Neonatal ICU pneumothoraces; (n=44)	Drain displacement, dysfunction
Petel D et al.[66]	2013	Canada	Percutaneous pigtail catheter versus tube thoracostomy for pediatric empyema: A comparison of outcomes Surgery.	Pigtail and dressing vs standard drain with sutures	Retrospective observational cohort analysis	Children with empyema; (n=43)	Drain displacement, occlusion or reintervention
Pierrepoint MJ et al.[67]	2002	UK	Pigtail catheter drain in the treatment of empyema thoracis	Pigtail vs standard drain; fixation method unclear	Retrospective observational cohort analysis	Children with empyema; (n=23)	Length of stay; drain replacement or adjustment
Rasihashemi SZ et al.[68]	2021	Iran	Comparison of the therapeutic effects of a pigtail catheter and chest tube in the treatment of spontaneous pneumothorax: a	Pigtail vs standard drain; fixation method unclear	Randomized controlled trial	Adult hospital patients requiring a pleural drain; (n=42)	Length of stay; pain; complications including displacement or obstruction

			randomized clinical trial study				
Roberts JS et al.[69]	1998	USA	Efficacy and complications of percutaneous pigtail catheters for thoracostomy in pediatric patients	Pigtail; suture; dressing	Retrospective observational cohort analysis	Paediatric ICU; (n=91; 133 procedures)	Complications including disconnection, displacement, or obstruction
Ross S et al.[70]	2016	UK	A pilot study of a dedicated ballooned intercostal drain	Intrapleural balloon; dressing	Observational trial	Inpatient pleural effusion drainage (n=20)	Drain displacement
Shi W et al.[71]	2023	China	Experience of a modified chest tube suture-fixation technique in uniportal thoracoscopic pulmonary resection	Sutures to skin and drain	Retrospective cohort case-control study of skin port closure and ICD fixation	Following uniportal thoracoscopic surgery (n=116)	Scarring, pain score, time until tube removal
Vaidya S et al.[72]	2022	Nepal	Comparative study between the use of pigtail catheters and traditional chest tube drain in cases with pneumothorax	Pigtail and suture vs standard drain with unclear fixation	Prospective comparative study	Adults with pneumothorax; (n=76)	Length of stay; pain; complications including displacement
Wei YH et al.[73]	2014	Taiwan	Pigtail catheters versus traditional chest tubes for pneumothoraces in premature infants treated in a neonatal intensive care unit	Pigtail vs standard drain with suture	Retrospective observational cohort analysis	Neonatal ICU pneumothoraces; (n=66; 86 procedures)	Length of stay; drain-free days; tube displacement/malfunction
Wood MD et al.[74]	2019	USA	Comparative evaluation of chest tube insertion site dressings: a randomized controlled trial	Adhesive dressings. Unclear if other methods used.	Randomised observational study	Medical, surgical and cardiothoracic ICUs (n = 127 patients; 236 drains)	Skin integrity, pain, absorbency, air leak and displacement.

Abbreviations: Intercostal chest drain (ICD); intensive care unit (ICU); neonatal intensive care unit (NICU); United Kingdom (UK); United States of America (USA); video-assisted thoracoscopic surgery (VATS)

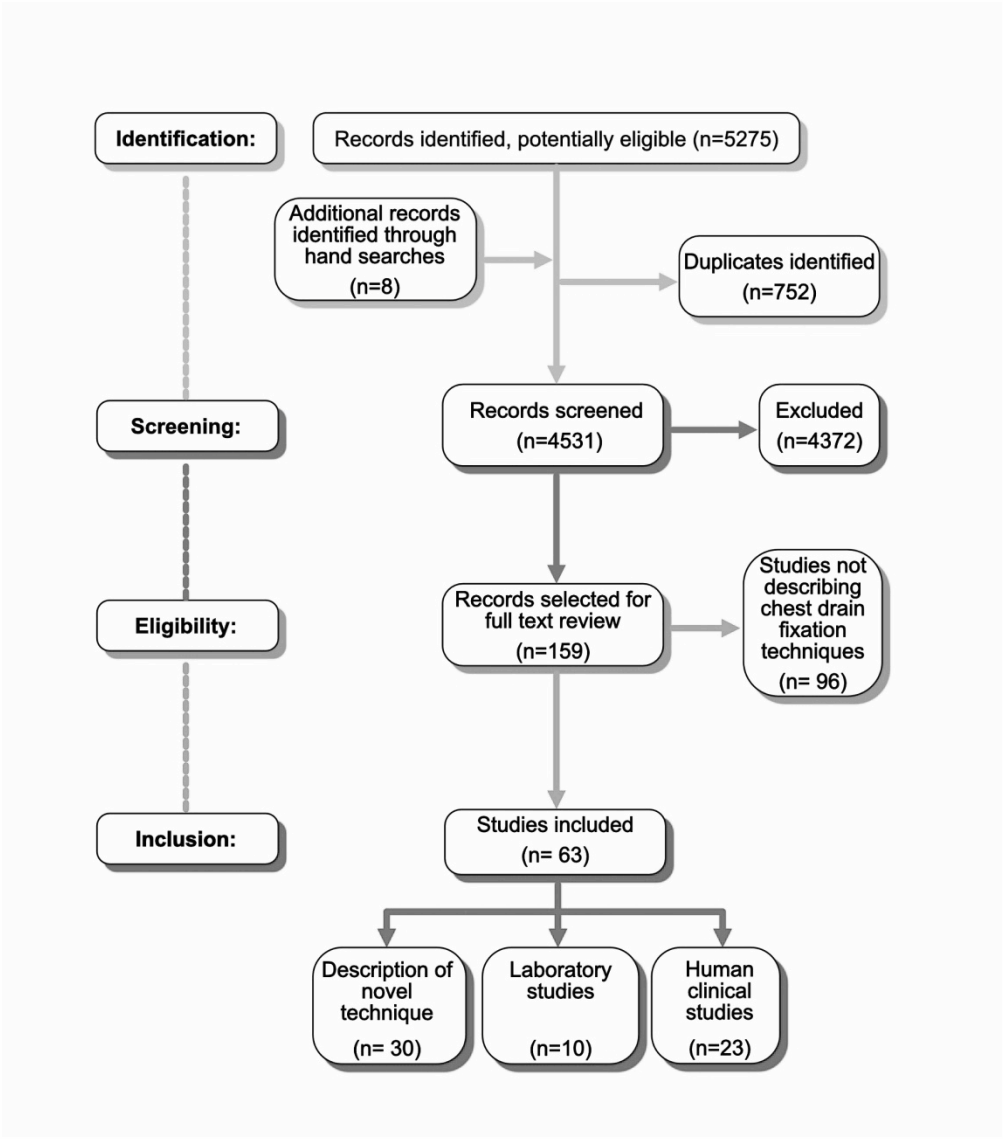


Figure 1. Flow diagram of literature search for intercostal chest drain fixation methods.

159x180mm (300 x 300 DPI)

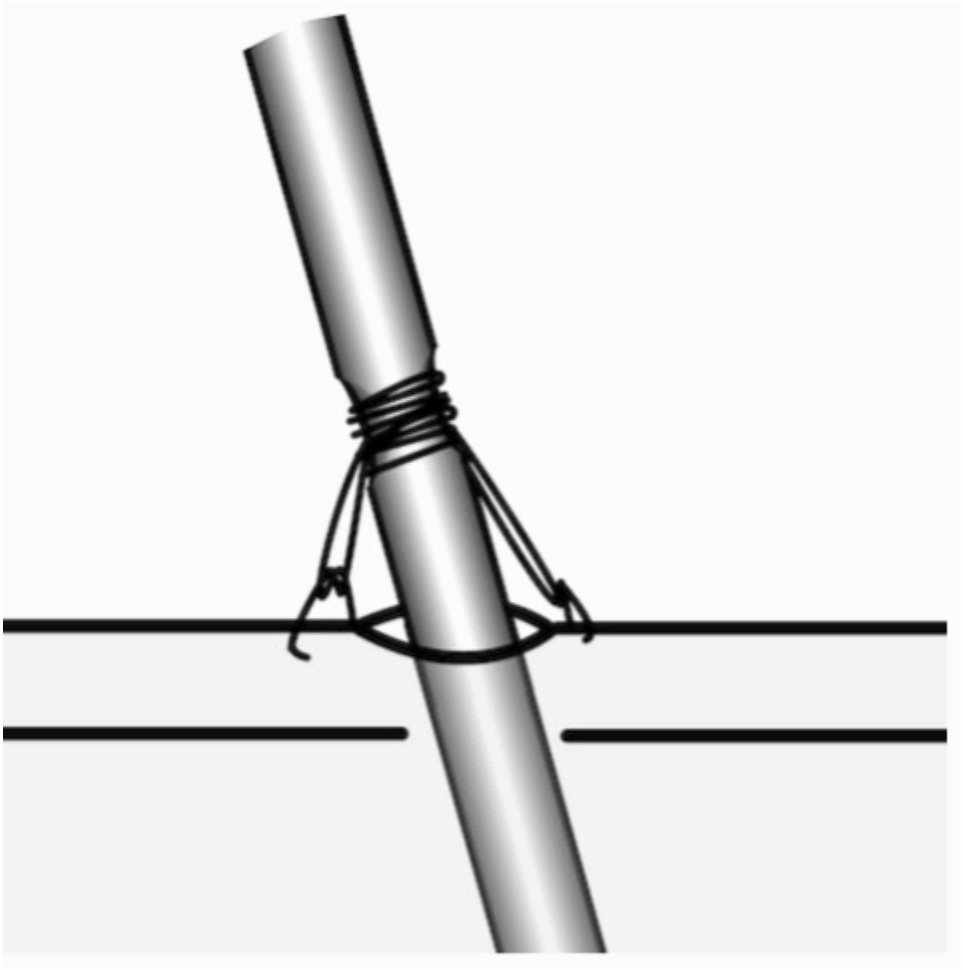


Figure 2. Kinking with a suture.

40x40mm (300 x 300 DPI)

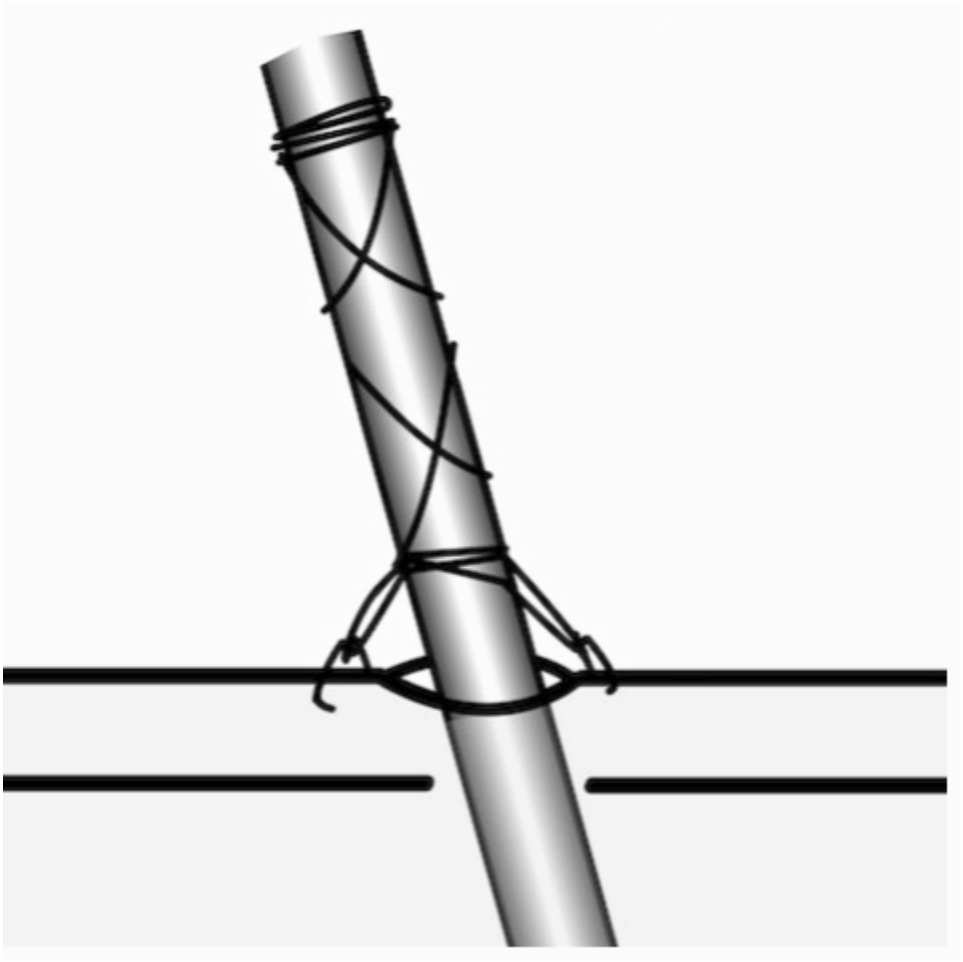


Figure 3. Roman Sandal.

40x40mm (300 x 300 DPI)

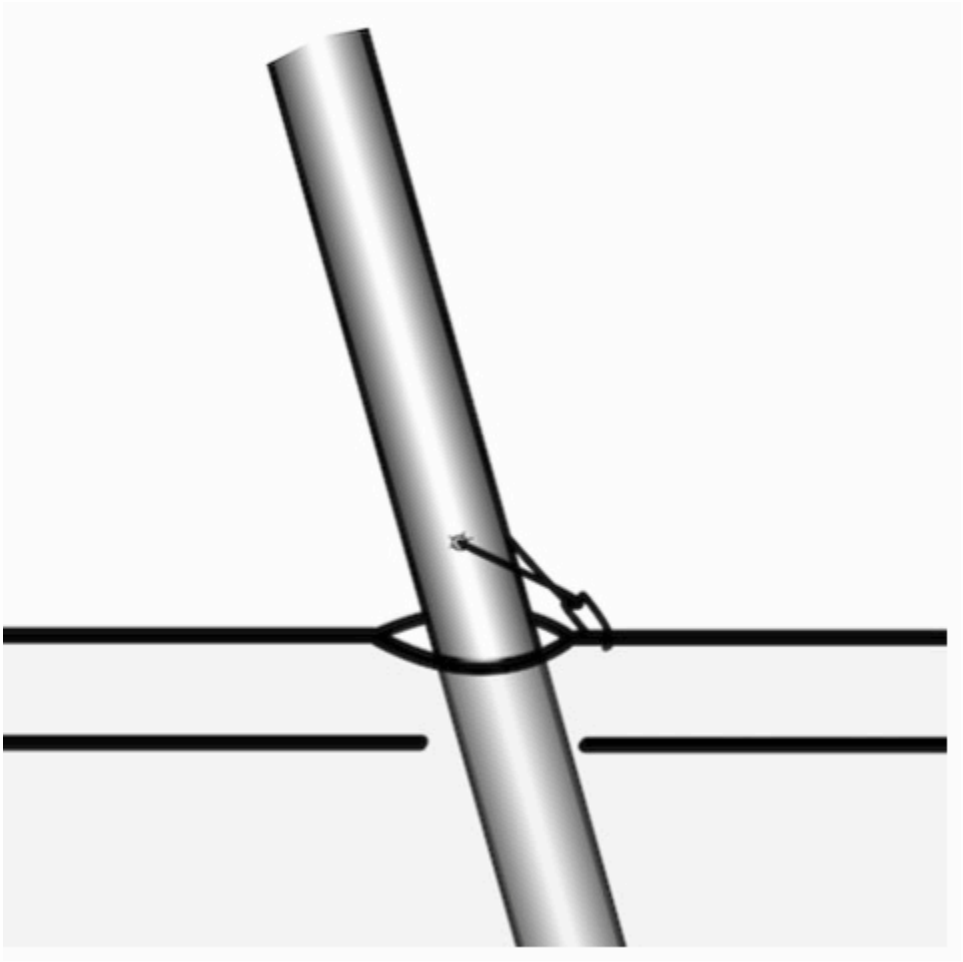


Figure 4. Suture through drain.

40x40mm (300 x 300 DPI)

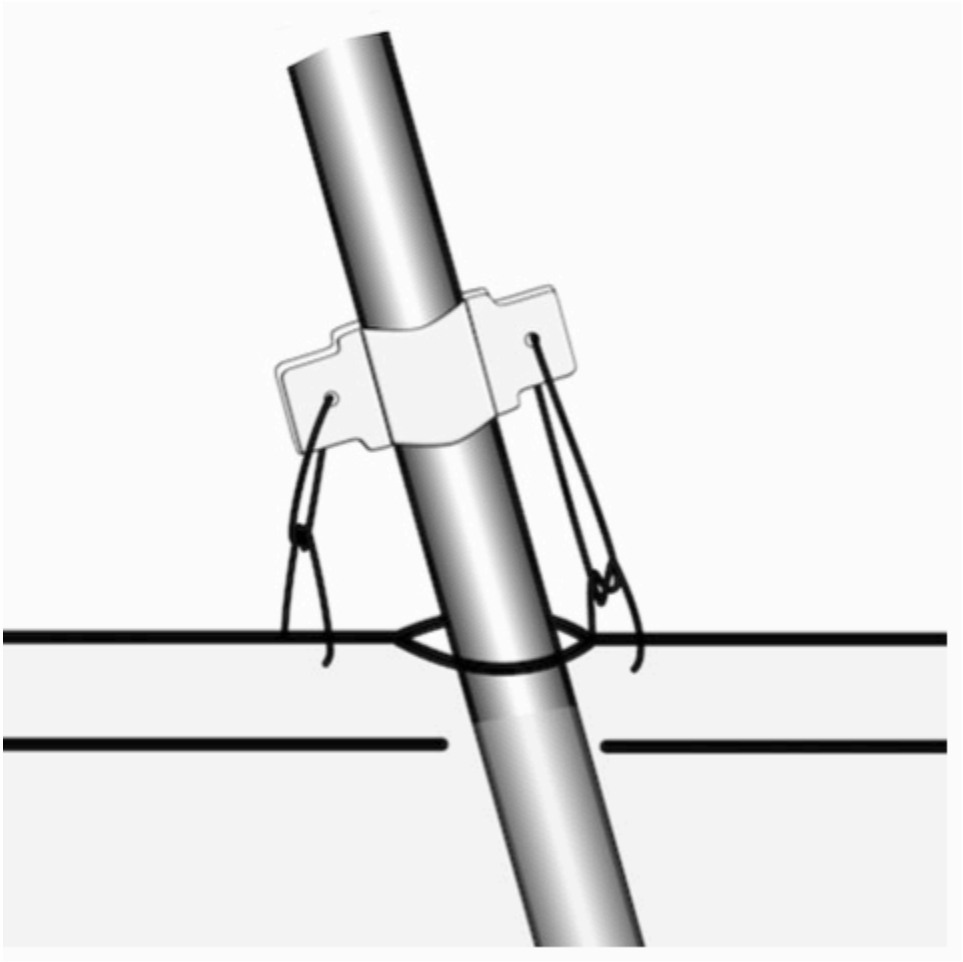


Figure 5. Drain with wings.

40x40mm (300 x 300 DPI)

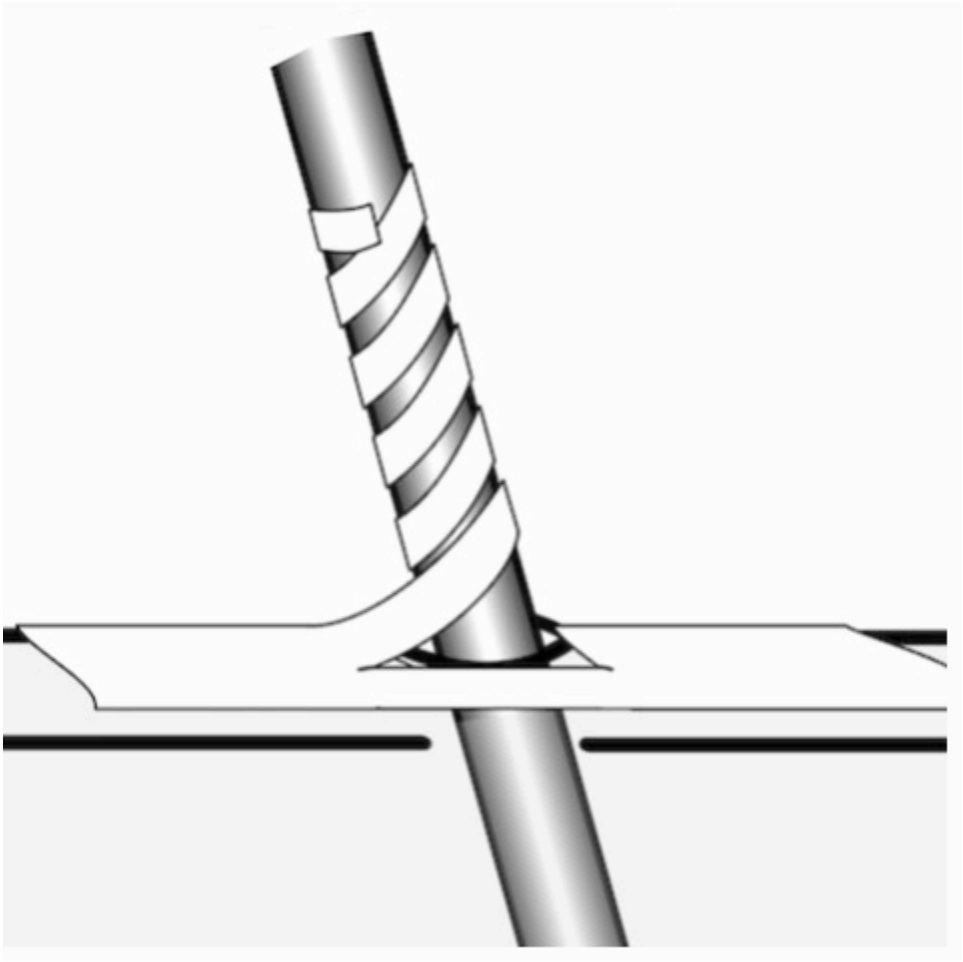


Figure 6. Adhesive tape.

40x40mm (300 x 300 DPI)

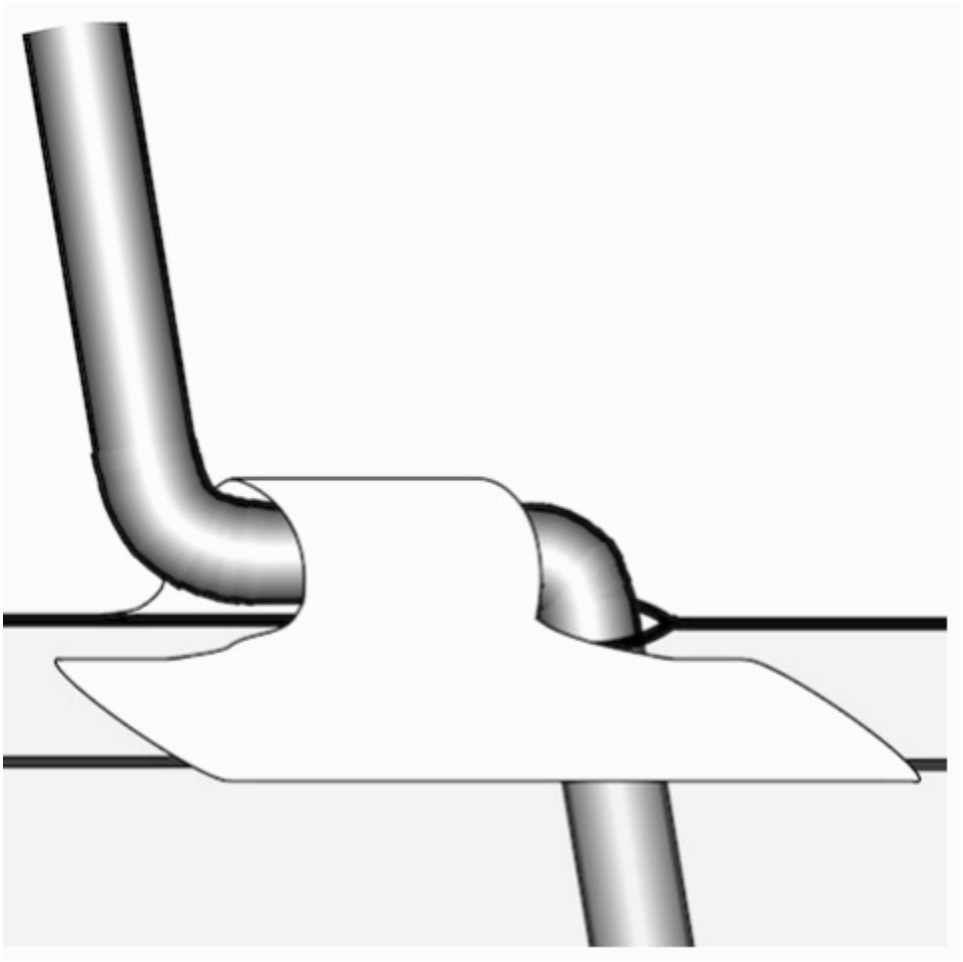


Figure 7. External flattening using a dressing or tape (a "bridge").

40x40mm (300 x 300 DPI)

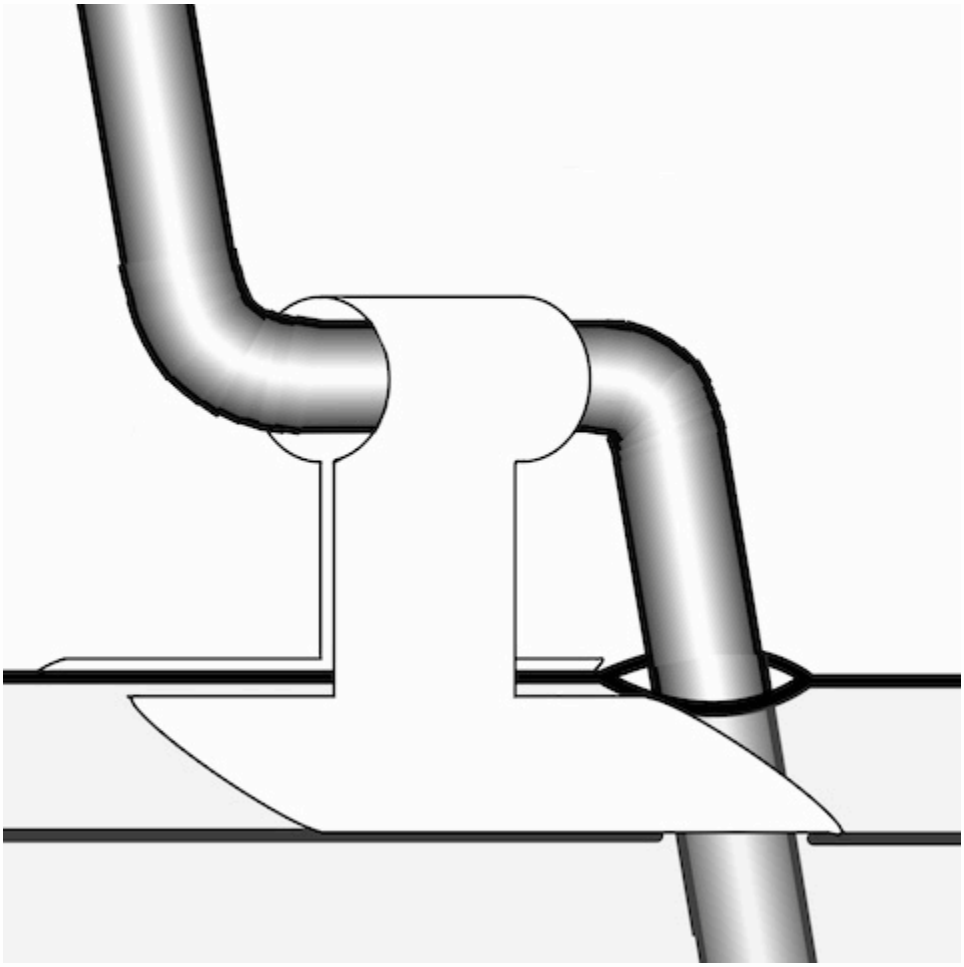


Figure 8. Dressing or tape with uses a mesentery

40x40mm (300 x 300 DPI)

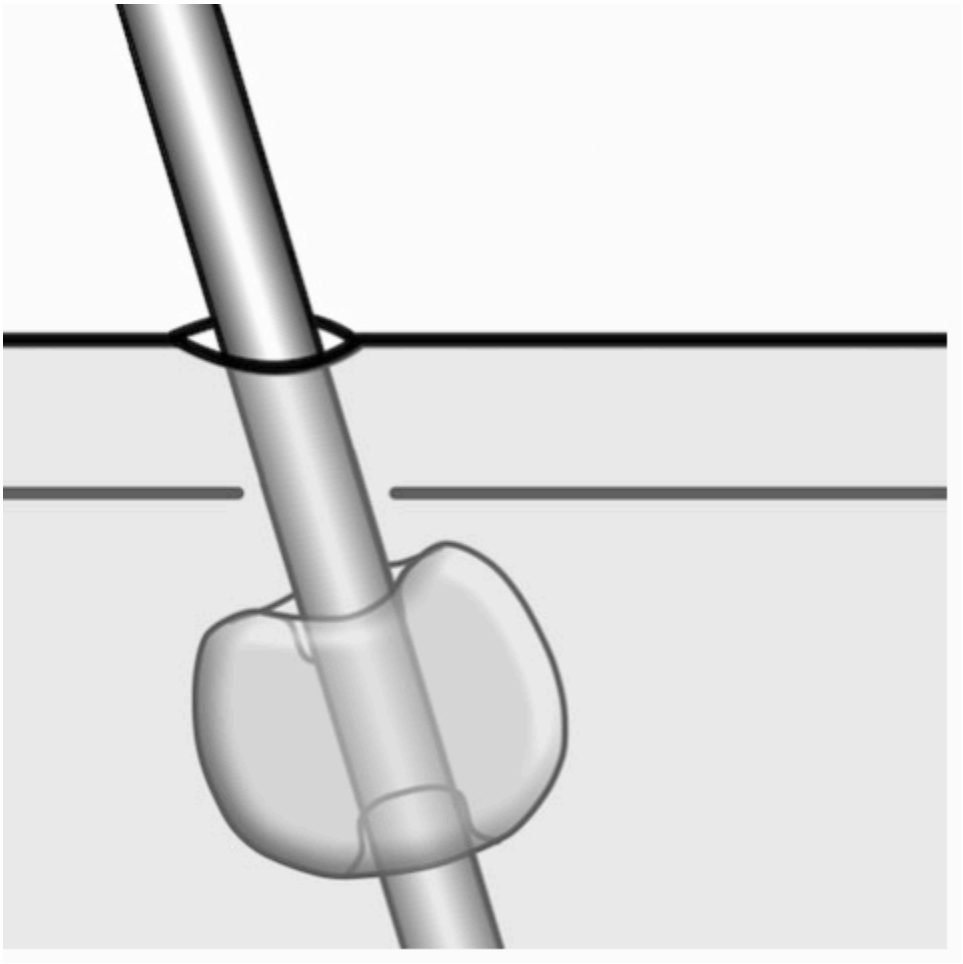


Figure 9. Drain with balloon.

40x40mm (300 x 300 DPI)

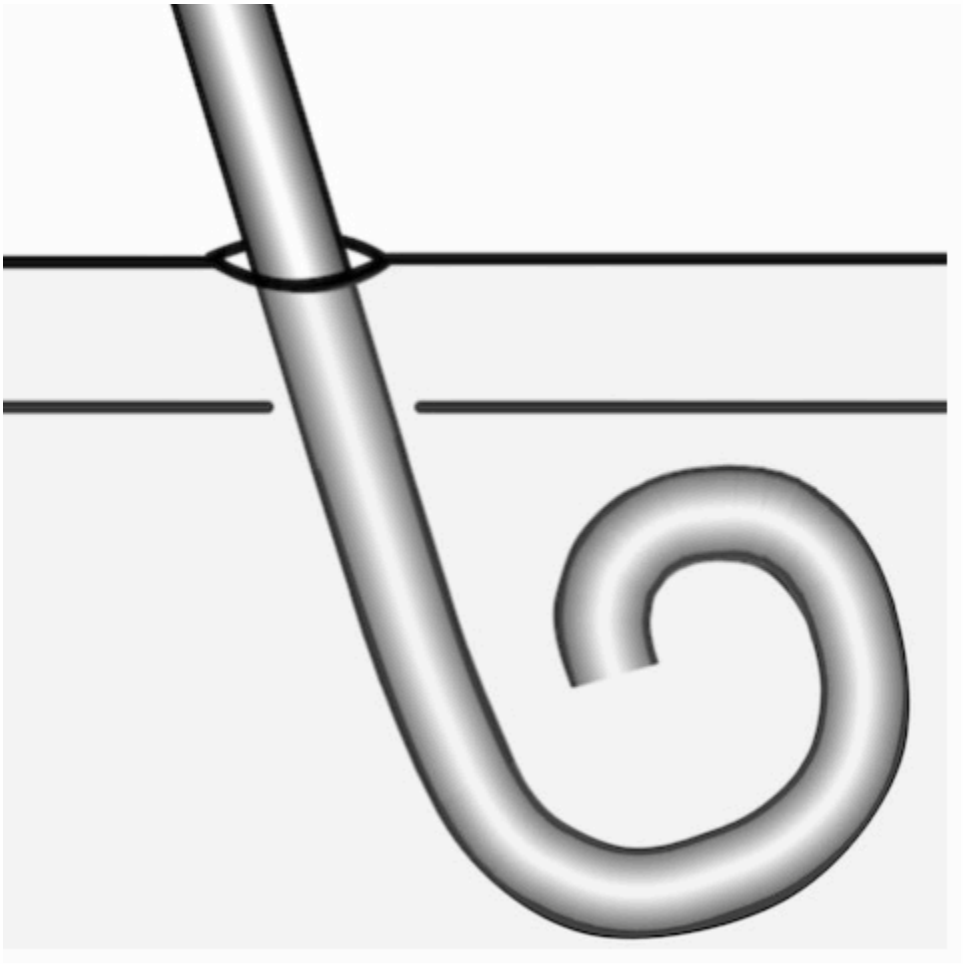


Figure 10. Pigtail drain.

40x40mm (300 x 300 DPI)

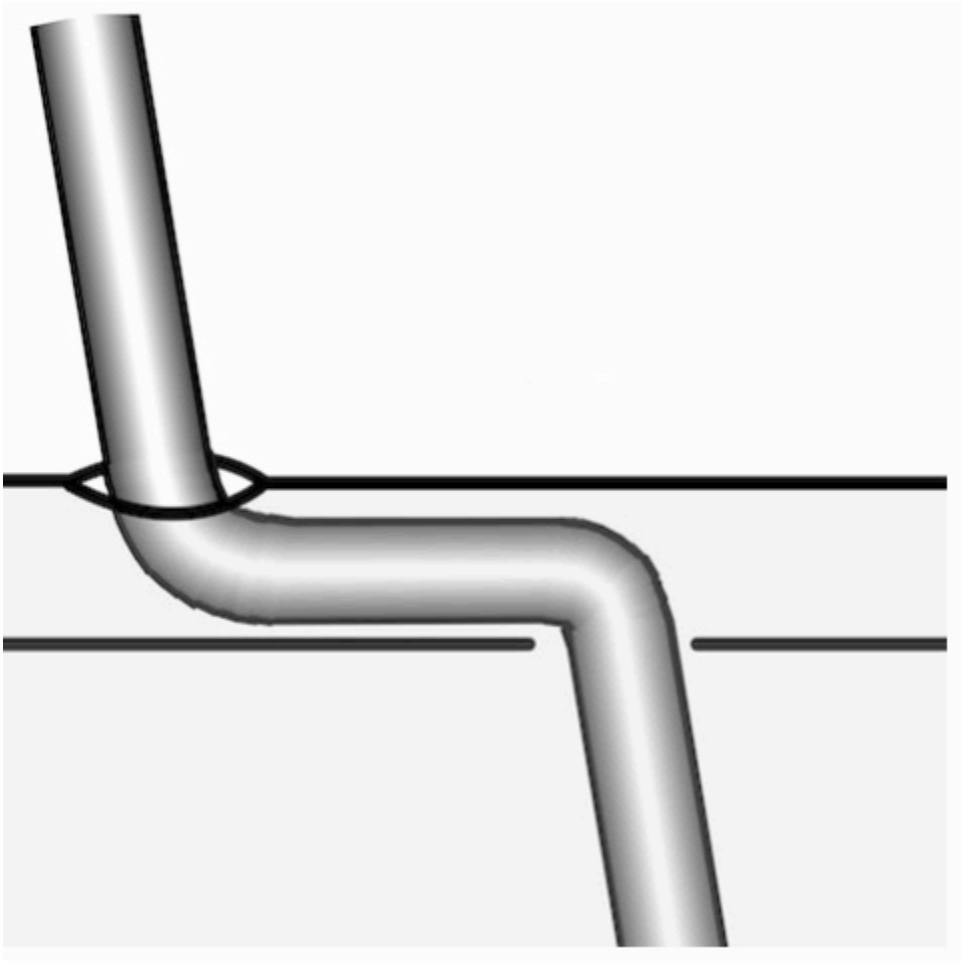


Figure 11. Tunnelled drain.

40x40mm (300 x 300 DPI)

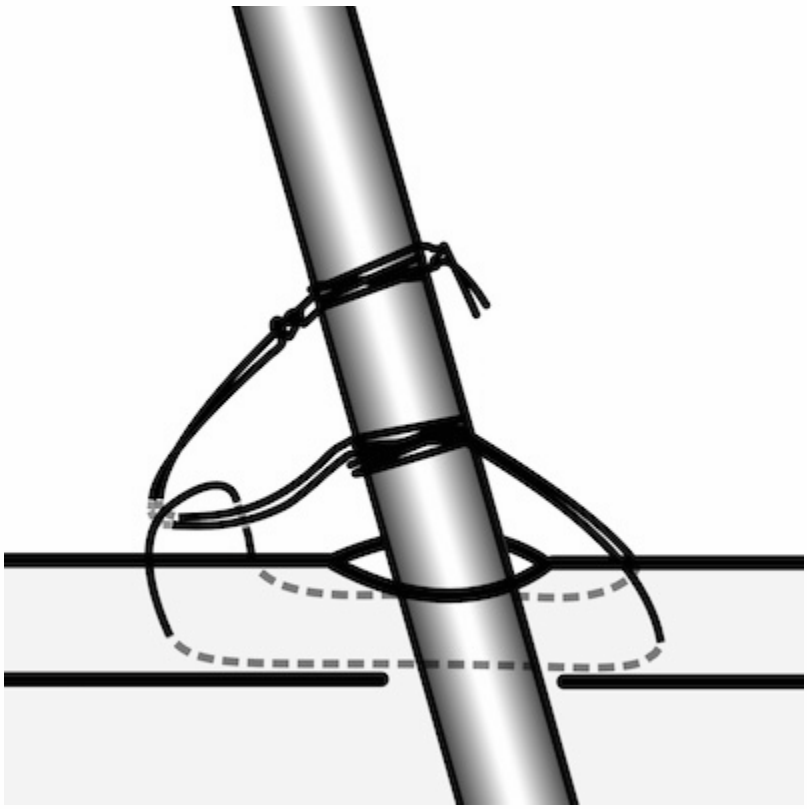


Figure 12. Modified Jo,burg knot suture fixation technique.

33x33mm (300 x 300 DPI)