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About the Journal

The Thai Journal of Surgery is the official publication of The Royal College of Surgeons of Thailand and is issued quarterly.

The Thai Journal of Surgery invites concise original articles in clinical and experimental surgery, surgical education, surgical history, surgical techniques, and devices, as well as review articles in surgery and related fields. Papers in basic science and translational medicine related to surgery are also welcome.

Aim & Scope

The Thai Journal of Surgery is dedicated to serving the needs of the members of The Royal College of Surgeons of Thailand, specifically the younger researchers and surgical trainees who wish to have an outlet for their research endeavors. The Royal College strives to encourage and help develop Thai Surgeons to become competent researchers in all their chosen fields. With an international outlook, The Thai Journal of Surgery welcomes submissions from outside of Thailand as well.

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References must be listed on a separate sheet in numeric order as referred to in the article, not alphabetically. A simplified Vancouver system is used. Only references mentioned in the text should be listed and should be selective with no more than 30 references except under unusual circumstances. Number references consecutively in the order in which they are first mentioned in the text. Identify references in text, tables, and legends by Arabic numerals (in superscript). The references must be verified by the author(s) against the original documents. Example forms of references are given below.

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2. Corporate Author:

- The Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gamma glutamyltransferase in blood. Scand J Clin Lab Invest 1976; 36:119-25.
- American Medical Association Department of Drugs. AMA drug evaluations. 3rd ed. Littleton: Publishing Sciences Group, 1977.

3. Personal Author(s):

- Osler AG. Complement: mechanisms and functions. Englewood Cliffs: Prentice - Hall, 1976.

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- Rhooder AJ, Van Rooyen CE, comps. Textbook of virology: for students and practitioners of medicine and the other health

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- o Chirappapha P, Arunnart M, Lertsithichai P, et al. Evaluation the effect of preserving intercostobrachial nerve in axillary dissection for breast cancer patient. Gland Surg 2019;8:599-608. doi:10.21037/gs.2019.10.06.

Abbreviations

Use only standard abbreviations of commonly used approved abbreviations. Avoid abbreviations in the title. The full term for which an abbreviation stands should precede its first use in the text unless it is a standard unit of measurement.

Statistics

All statistical analyses and the statistical software used must be concisely described. Descriptive statistics for quantitative variables must include an appropriate central tendency measure (e.g., mean or median) as well as a corresponding measure of spread (e.g., standard deviation or range or interquartile range). Categorical variables must be summarized in terms of frequency (counts) and percentage for each category. Ordinal variables can be summarized in terms of frequency and percentage, or as quantitative variables when appropriate. Statistical tests must be named and p-values provided to 3 decimal places. P-values less than 0.001 should be written "< 0.001" and p-values approaching 1 should be written "0.999".

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(see Format https://bit.ly/3IaP4ZB)

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literature review of previous published, related results. These related results must be compared with those of the authors' study, and the differences clearly stated along with plausible explanations. New unexpected findings, especially from subgroup analyses or those for which the research was not designed, should be considered hypothetical and stated as such. Any plausible, relevant clinical application should be indicated. Finally, any significant limitations of the study must be mentioned and possible extensions of research should be briefly provided. **Conclusion,** which should be concerned with answering the research question posed by the current study, should not be summarizing results of previous studies or recommendations. An **Acknowledgement** section can be added at the end of the article. The Reference list should be in the format as described previously.

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Use the common format. Emphasis is on clinician comprehension. The **Abstract** uses the same common structured format. In the **Main text,** the **Introduction,** in addition to the usual context setting and rationale, should also contain explanations and descriptions of basic science concepts at the level of the educated layman. The **Methods** section should still be concise with sufficient detail for others to replicate the experiment, but one or two paragraphs in between explaining basic processes in plain English would be helpful. In the **Results** section, similar conciseness is still the rule, but a brief simplified summary of the findings should be provided. In the **Discussion,** clinical implications should be clearly stated. The **Conclusion,** again, should answer the research question.

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We encourage publication of case series or case reports if a comprehensive review of the literature is included, with the aim of helping the clinician manage rare and challenging diseases or conditions based on best available evidence in conjunction with practical, local experience. For the Thai Journal of Surgery, this implies that the case report format differs somewhat from that of the common format for research articles.

Abstract: Need not be structured. State objective of the case presentation, present a summary of the case, the outcome and learning points in one concise paragraph.

Main text: An **Introduction** is required to set the importance or relevance of the case within the current clinical context, based on a comprehensive literature review. A brief review of anatomy and pathology, or pathophysiology can be provided. **Report of the case** then follows with sufficient details on clinical presentation, diagnostic work up, interesting features, and decision making, to be useful for other surgeons. Surgical management should be concisely described and should be accompanied by high-resolution photographs or high-quality drawings and diagrams, if possible. Unique features of the case, and typical or general features should be distinguished. **Results** of management and follow-up information should be provided. **Discussion** then places the clinical, diagnostic, surgical and pathological features of the case within current knowledge or context and provides reasons for decision making and surgical management or otherwise. Wider implications of the case should be emphasized; for example, when management contradicts existing guidelines or when feasibility of some never-before performed surgery has been demonstrated. The **Conclusion** simply summarizes the case in terms of management implications.

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Editorial

Kusuma Chinaroonchai, MD.
Editor of The Thai Journal of Surgery

In this issue, we present a diverse and thought-provoking selection of four original studies, one case report, and one surgical education that reflect the evolving landscape of surgical innovation and perioperative care. We begin with a high-volume experience on **clipless laparoscopic cholecystectomy using a knot pusher**, demonstrating a safe alternative in over 500 cases. A comparative study on **sentinel lymph node biopsy techniques for breast cancer** evaluates single versus separate incisions, offering insights into surgical efficiency outcomes. Oncologic outcomes are further explored in a study analyzing **recurrence rates in rectal cancer patients with suspected lateral pelvic lymph node metastasis** following neoadjuvant CRT and TME. Expanding into critical care, an investigation into the **ultrasonic assessment of diaphragm function** highlights its utility in guiding ventilator liberation in perioperative patients. A compelling case report showcases the role of **intraoperative indocyanine-green video angiography in thoracic spinal dural arteriovenous fistula surgery**, emphasizing the value of precision mapping. Finally, a retrospective review on the **30-day mortality after palliative shunt surgery for cyanotic congenital heart disease** at a regional referral center provides key data relevant to pediatric and cardiac surgical care. Collectively, these contributions offer valuable clinical insights and underscore the continual pursuit of excellence in surgical science.

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Original Article

Clipless Laparoscopic Cholecystectomy with Knot Pusher: Experience from More Than 500 Cases

Phichai Phongmanjit, MD

Department of Surgery, School of Medicine, Mae Fah Luang University, Chiang Rai, Thailand

Abstract

Objective: This study aims to demonstrate that laparoscopic cholecystectomy utilizing the extracorporeal sliding knot technique with a knot pusher can achieve satisfactory outcomes, such as no dislodgement of the tied cystic duct and minimal complications. The technique was efficient, secure, and cost-effective, with no instances of accidental knot failure observed, and requiring only a single nylon suture for knot tying.

Materials and Methods: A retrospective study was conducted on the elective symptomatic gallstone disease treatment outcomes via laparoscopic cholecystectomy (LC) utilizing the extracorporeal sliding knot technique with a knot pusher. The diagnosis was confirmed in all cases using ultrasound, and no instances of acute cholecystitis were included in this study. This study was carried out at the General Surgery Department of Chiangrai Prachanukroh Hospital between September 2008 and August 2019.

Results: The results of this study indicated favorable outcomes for LC performed using this method. A total of 512 patients were included, comprising 94 males and 418 females. The mean age of the participants was 49.1 years, with an age range of 21 to 91 years. The average duration of surgery was 35 minutes, ranging from 16 to 72 minutes. Blood loss during surgery averaged 15 ml, ranging from 2 to 120 ml. The average hospital stay was 2.5 days, ranging from 1 to 5 days. No serious complications related to cystic duct ligation were observed using the extracorporeal sliding knot technique. The average time required to tie all knots in each case was 4 minutes, ranging from 2 to 7 minutes.

Conclusion: Laparoscopic cholecystectomy using the extracorporeal sliding knot technique with a knot pusher enhances cystic duct closure efficiency by simplifying surgery, lowering complications, and reducing costs. It ensures secure closure, is easy to learn, and adds minimal time to the procedure compared to clipping, making it an effective alternative technique.

Keywords: Laparoscopic cholecystectomy, Extracorporeal knotting, Sliding knot, Knot pusher

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Introduction

Gallstone disease is a prevalent condition that poses significant clinical challenges. Laparoscopic cholecystectomy (LC) has transformed the management of gallstone disease, providing numerous advantages over traditional open surgery, including reduced postoperative pain, shorter hospital stays, and expedited recovery times.[1-5] Approximately 750,000 laparoscopic cholecystectomies are performed annually in the United States, representing about 90% of all cholecystectomies, with a notable decline in the overall serious complication rate since its inception.[6,7] The cystic duct and its associated vessels are critical components in the surgical management of gallstone disease. Various techniques have been developed for cystic duct closure during laparoscopic cholecystectomy.[8,9] Endo-clips are the most commonly utilized devices for bile duct closure, with multiple types available, indicating no consensus on a single optimal device. Intracorporeal knot tying is an alternative technique; however, it requires a higher level of technical skill to master. Among these, the extracorporeal knotting method offers distinct benefits over the intracorporeal approach, including greater simplicity, reduced procedural time, and a less steep learning curve for surgeons.[10-12] In our practice, we utilize Nylon No. 1 suture as the preferred material for securing the cystic duct and vessels. This technique involves bringing both ends of the nylon suture outside the abdomen to perform a sliding knot extracorporeally. Subsequently, a knot pusher is employed to secure the knot firmly around the cystic duct and its associated vessels.

Materials and Methods

A retrospective analysis of LC utilizing extracorporeal knot (Figure 1) and knot pusher (Figure 2) was performed between September 2008 and August 2019. This present study was conducted using medical records from the General Surgery Department of Chiangrai Prachanukroh Hospital. All procedures in this study were performed by a single surgeon. The inclusion criteria included patients aged 18 years or older of both genders with elective symptomatic gallstone disease, confirmed through ultrasound examination. Cases of acute cholecystitis were excluded from this study. Ethical approval was taken from the institute board members of Chiangrai Prachanukroh Hospital. Patient data were extracted and analyzed, including demographics, surgical time, hospital stay, and postoperative complications.

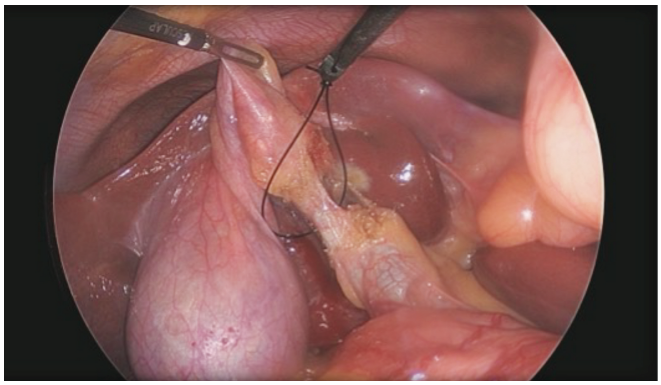

Figure 1 LC, knot pusher

Figure 2 Knot pusher

Procedure

Most patients without a documented allergic reaction to cephalosporins receive preoperative Cefazolin (1 g). In our practice, laparoscopic cholecystectomy is typically executed using a three-port approach. The port arrangement follows a modified standard protocol for laparoscopic cholecystectomy, incorporating a 10-mm optical port at the infraumbilical fold, along with two additional 5-mm ports positioned in the epigastrium and the right subcostal area along the midclavicular line. This insertion method is referred to as the "10-5-5" configuration. For cases without previous surgical procedures, the first port is introduced into the abdominal cavity using a Veress needle. In contrast, an open technique is utilized for patients with a history of prior surgeries. The subsequent ports are inserted under direct visualization provided by

the camera port. Dissection of the cystic duct and artery follows. The gallbladder is grasped at Hartmann's pouch using an instrument inserted through the right subcostal port, ensuring adequate tension on the cystic duct. The critical view of safety is then established. A nylon No.1 suture, measuring 90 cm in length, is threaded through the epigastric port to hook around the cystic duct. An extracorporeal sliding knot is created. This knot is then pushed inside the abdomen to ligate firmly around the cystic duct, with the initial knot placed at the junction of the cystic duct and Hartmann's pouch. A second knot is subsequently tied at a distance medial to the prior knot, allowing for safe division of the cystic duct. Ligation of the cystic artery at both its proximal and distal ends is conducted before transection. A fourth 5 mm port may be added in rare instances requiring enhanced access or maneuverability. Gallbladder extraction is performed using an extraction bag.

Results

This retrospective analysis examined the outcomes of symptomatic gallstone treatment via laparoscopic cholecystectomy (LC) utilizing the extracorporeal sliding knot technique with a knot pusher at the General Surgery Department of Chiangrai Prachanukroh Hospital from September 2008 to August 2019. The findings indicated favorable results for LC performed with this method. Among the 512 patients, 94 (18.4%) were male and 418 (81.6%) were female. The mean age of participants was 49.1 years, spanning from 21 to 91 years. Coexisting medical conditions were present in 32% of the study population, including hypertension, diabetes, and chronic obstructive pulmonary disease (COPD), as detailed in Table 1. The average duration of surgery, measured from incision to skin suture, was 35 minutes, with a range of 16 to 72 minutes. Blood loss averaged 15 ml, with a variation from 2 to 120 ml. Patients had an average hospital stay of 2.5 days, ranging from 1 to 5 days, as shown in Table 2. Notably, there were no instances of bile leakage or other complications associated with cystic duct ligation. The time required for tying all the knots in each case varied between 2 and 7 minutes, averaging around 4 minutes (this item was collected from the last 2 years of studying).

Table 1 Demographics Data

Demographics	Case (%)
Gender	
Male	94 (18.4)
Female	418 (81.6)
Age	
Mean: Year	49.1
Range: Year	21-91
Co-morbidity	164 (32)
Hypertension	112 (21.9)
Diabetes	37 (7.2)
COPD	21 (4.1)

Table 2 Clinical Data

Clinical data	
Operation time	
Mean: minute	35
Range: minute	16-72
Blood loss	
Mean: ml.	15
Range: ml.	2-120
Hospital stays	
Mean: Day	2.5
Range: Day	1-5
Tying time*	
Mean: minute	4
Range: minute	2-7

*This data was collected from the last 2 years of studying

Discussion

This retrospective study included consecutive elective laparoscopic cholecystectomy (LC) cases performed for symptomatic gallstone disease. The demographic characteristics and comorbidities of the study population were suitable for undergoing general anesthesia.

Within the domain of surgical knot-tying techniques, I advocate using a simple sliding knot, as shown in Figure 3. This method demonstrates remarkable effectiveness in securely ligating the cystic duct and its associated vessels across various clinical scenarios. The significant advantages of employing extracorporeal knot ligation become particularly evident in cases where the cystic duct exhibits a substantial diameter, making alternative duct ligation techniques challenging to implement with the requisite confidence.[13]

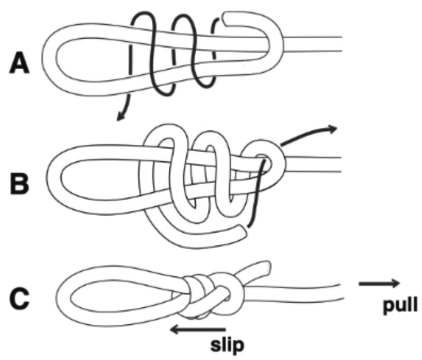

Figure 3 Sliding knot

The extracorporeal knot-tying technique involves forming a knot outside the body and subsequently deploying it into position using a specialized knot pusher device. This approach circumvents the complexities often associated with intracorporeal knot-tying methods. Our data indicate that the average surgical duration for this procedure is approximately 35 minutes, which aligns with established benchmarks for laparoscopic cholecystectomy (LC), thereby reflecting efficient operational standards at our medical center.[14] Furthermore, an average hospital stay of 2.5 days underscores the efficacy of our postoperative care protocols and patient recovery processes.[15-18]

Notably, the absence of complications such as bile duct leakage, biloma, intra-abdominal collections, or postoperative bleeding in all cases attests to the surgical team's proficiency and strict adherence to established protocols. The reduced length of hospital stays not only enhances patient recovery but also contributes to cost-effectiveness within our healthcare system, while the average time for knot tying is recorded at 4 minutes, potentially longer than that required for duct endo-clip applications. Surgeons typically experience a significant decrease in closure time as they gain familiarity with this technique. Over time, consistent application of this method can lead to improved operational efficiency and further reductions in operative durations.

Gallstone disease is a prevalent condition in contemporary clinical practice. Laparoscopic cholecystectomy (LC) has become the gold standard treatment, replacing traditional open cholecystectomy due to its minimally invasive nature and improved patient outcomes. With the increasing frequency of LC procedures, it is essential to consider both the safety and cost-effectiveness of the surgery.

My journey with laparoscopic cholecystectomy began in 1997 when I invited a distinguished professor of surgery from Siriraj Hospital, Mahidol University, to demonstrate the procedure. Since then, I have successfully performed over 1,000 laparoscopic cholecystectomies. However, I am reporting on 500 cases due to incomplete medical records prior to 2008. Since 1999, I have employed the extracorporeal knotting technique using a knot pusher for cystic duct closure. This technique is the sole method employed for bile duct closure in elective laparoscopic cholecystectomy in my practice, resulting in a limited sample size for comparison with alternative closure techniques. This extracorporeal method enhances surgical efficiency through several key factors:

1. Simplicity of Technique: The extracorporeal knotting method is generally simpler than intracorporeal techniques. It allows for easier manipulation and placement of sutures outside the abdominal cavity, reducing the complexity involved in securing the cystic duct. This simplicity can lead to a more straightforward learning curve for surgeons, particularly those who may be less experienced with laparoscopic suturing techniques.[19,20]

2. Reduced Risk of Complications: Studies indicate that extracorporeal knotting may result in fewer intraoperative complications compared to clip application. For instance, complications such as clip slippage and bile leakage are less common with secure knots, thereby minimizing the need for additional interventions during surgery.[19,21] The potential for complications with clips, such as migration or spillage of stones, can extend the operative time and increase patient risk.[19,22]

3. Cost-Effectiveness: While the initial operative time may be slightly longer for extracorporeal knotting compared to clip application, the overall cost-effectiveness is favorable. The use of sutures eliminates the need for expensive clip devices, which can accumulate significant costs in high-volume surgical settings.[19,21]

4. Secure Closure: The extracorporeal technique allows for a more secure cystic duct closure. The use of a sliding knot ensures that the ligation is tight and stable, reducing the risk of postoperative complications such as bile leaks, which can lead to increased morbidity and additional surgical interventions.[20,21]

5. Time Efficiency with Experience: Although initial reports suggest that extracorporeal knotting may take longer than clip application, as surgeons gain experience with this technique, the time required for closure

decreases significantly. Over time, routine use of this method can lead to improved efficiency and reduced operative times.[21,22]

Knot tying

The knot used to tie the Extracorporeal knot must be strong and easy to tie. The first and most widespread knot is probably the Roeder knot.[23] It is a strong knot, but in my opinion, it is complicated to tie. Learning to tie it correctly is not easy. So, I chose the Sliding knot, which is equally strong but not complicated, as shown in Figure 3.[24] We can learn how to tie this knot quickly. It takes no more than 30 seconds to tie one knot.

Phichai's maneuver

One of the critical steps in laparoscopic cholecystectomy (LC) utilizing a knot pusher involves threading a nylon suture through the cystic duct and exteriorizing it through the abdominal wall to facilitate knot formation. Inexperienced surgeons often encounter significant challenges during this phase, particularly when attempting to pass the nylon through the cystic duct. A common issue arises when the nylon suture, once released from the dissector's grip, tends to slip out, leading to frustration and increased operative time.

To address this challenge, I propose a straightforward technique, which I have termed "Phichai's maneuver," as shown in Figure 4. This method involves applying gentle pressure with the fingers on the nylon suture at the edge of the trocar. This stabilization prevents movement of the nylon, as shown in Figure 5, thereby allowing the dissector to securely grasp and easily extract the suture from the abdominal cavity. This technique not only enhances efficiency but also minimizes potential complications associated with improper handling of the nylon during laparoscopic procedures. By mastering this maneuver, surgeons can improve their proficiency in executing extracorporeal knot-tying techniques, ultimately contributing to safer and more effective surgical outcomes in laparoscopic cholecystectomy.

Significantly, the thickness or width of the cystic duct did not impede the ability to tie knots using the knot pusher technique.

We feel that because the LC is a frequently performed laparoscopic procedure, it is a good practice ground to learn this extracorporeal knot tying, which would be very useful in simplifying cystic duct closure, reducing complication rates, and being cost-effective.

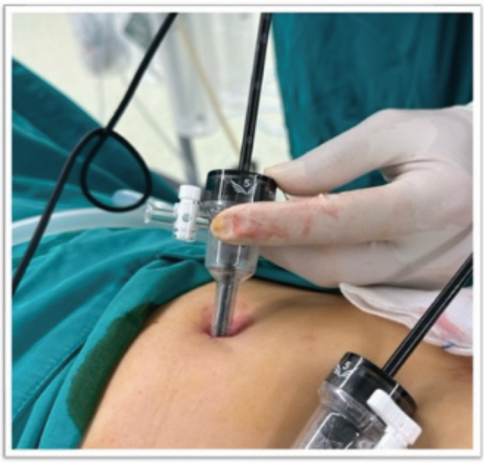

Figure 4 Phichai's maneuver

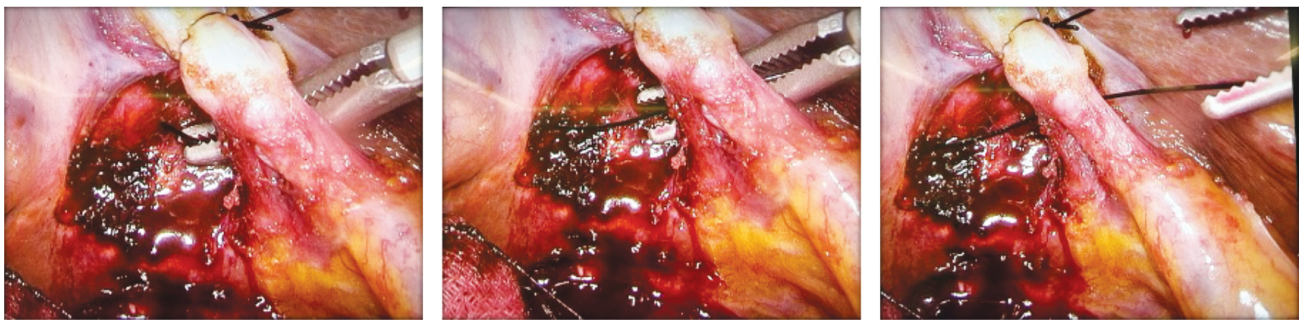

Figure 5 Effect of Phichai's maneuver

Conclusion

Laparoscopic cholecystectomy (LC) utilizing the extracorporeal sliding knot technique with a knot pusher improves the efficiency of cystic duct closure by simplifying the surgical process, reducing complication rates, being cost-effective, ensuring secure closure, and allowing for increased efficiency with practice. It is easy to learn, and the ligation time is only a few minutes more than clipping. These factors collectively contribute to enhanced patient outcomes in laparoscopic cholecystectomy procedures.

Mastering the use of the knot pusher in laparoscopic cholecystectomy requires minimal training. Once proficient, its effectiveness should be studied and compared with alternative methods of bile duct closure.

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Original Article

Comparison of Single Incision and Separate Incision Techniques in Sentinel Lymph Node Biopsy for Breast Cancer

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Abstract

Background: Breast cancer is the most common malignancy among Thai women, with approximately 50 new cases per 100,000 population annually. Sentinel lymph node biopsy (SLNB) is crucial for staging early breast cancer, and the choice of surgical technique can significantly impact outcomes. Identification of SLN using blue dye alone simplifies the procedure while remaining effective for resource-limited hospitals lacking frozen section analysis. Prior studies of single-incision SLNB focused on breast-conserving surgery.

Objective: This pilot study aimed to compare the single-incision and separate-incision techniques for SLNB in breast cancer patients, focusing on node harvesting, operative time, and postoperative complications.

Materials and Methods: Data were collected from Ubonratchatani Cancer Hospital between 2020 and 2024. A total of 59 patients with early-stage, clinically node-negative breast cancer were included: 31 underwent SLNB via the single-incision technique, and 28 via the separate-incision technique. Patients with biopsy-proven axillary node metastasis or those who received neoadjuvant chemotherapy were excluded. Multivariable regression analysis was used to assess key factors influencing node harvesting.

Results: The single-incision technique led to a 46% and 40% increase in lymph node yield compared to the separate-incision method in mastectomy with breast-conserving surgery and mastectomy alone, respectively. Operative times were shorter for the single-incision group, and postoperative complications, including seroma and wound infection, were less frequent. Tumor location, HER-2 status, and histologic grade significantly affected node harvesting. Both techniques showed comparable safety profiles, but the single-incision approach demonstrated improved surgical efficiency. Additionally, both techniques yielded similar survival outcomes, with no statistically significant differences in short-term overall survival and progression-free survival.

Conclusion: The single-incision technique for SLNB benefits node harvesting and operative efficiency while maintaining comparable postoperative complication rates. These findings suggest that the single-incision method may enhance patient outcomes, but further research is needed to validate these results and explore long-term oncological benefits.

Keywords: Breast cancer, Sentinel lymph node biopsy, Single-incision technique, Node harvesting, Surgical outcomes

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Introduction

Breast cancer is the most common malignancy among Thai women, with an incidence of approximately 50 new cases per 100,000 population per year.[1] The 5-year survival rates vary according to the stage of the disease: 94.4% for stage I, 85.0% for stage II, 56.6% for stage III, and 28.3% for stage IV.[2] Currently, The increasing availability of mammographic screening has led to a higher detection rate of early-stage breast cancer, which is associated with a favorable prognosis and a high likelihood of cure. Surgery remains the primary treatment modality for early-stage breast cancer.[3]

The sentinel lymph node biopsy (SLNB) is a minimally invasive technique that is crucial for staging and treatment planning in early-stage breast cancer patients who do not have clinically evident axillary lymph node involvement before surgery.[4] The ACOSOG Z0011 trial demonstrated that in patients undergoing breast-conserving surgery (BCS) with postoperative radiotherapy, those with 1-2 positive sentinel lymph nodes had similar rates of overall survival disease, free survival, and locoregional recurrence whether they underwent complete axillary lymph node dissection (ALND) or not.[5,6] Similarly, studies in patients undergoing mastectomy with positive sentinel lymph nodes (1-3 nodes) showed no significant differences in 5-year overall survival and recurrence-free survival between those who underwent ALND and those who received axillary radiotherapy instead.[7,8] A systematic review and meta-analysis further supported these findings, showing no differences in 5-year overall survival, disease-free survival, or recurrence rates between these treatment approaches.[9]

Sentinel lymph node biopsy can be performed using various tracers, including blue dye (BD), technetium-99m labeled nanocolloid (Tc-99m), and indocyanine green (ICG). The blue dye technique is widely used due to its simplicity and accuracy.[10] This dye binds to albumin and migrates to the sentinel lymph node, which is believed to be the first lymph node receiving drainage from the breast.[11] Surgeons use anatomical landmarks[12] and observe the dye's color at the lymphatic tracts to guide sampling.

Few studies have explored and developed techniques for single-incision sentinel lymph node biopsy (SLNB) and breast-conserving surgery (BCS). Brendan P et al.,[13] have published a technique for performing BCS using a single incision, which offers benefits such as reduced operative time and lower rates of complications, including pain, bleeding, numbness, and infection while maintaining equivalent quality in lymph node harvesting compared to the traditional separate-incision approach. However, this technique is primarily applicable to patients with tumors located in the upper outer quadrant of the breast.

Zhang et al. conducted a study comparing surgical outcomes between single-incision mastectomy with sentinel lymph node biopsy and separate-incision techniques. Using carbon nanoparticles and indocyanine green, they utilized a dual technique for sentinel lymph node identification. Their findings demonstrated that the single-incision approach was associated with shorter operative time, increased lymph node harvest, and reduced numbness in the axillary region.[14]

In rural or remote parts of developing nations such as Thailand, patient attitudes and difficulties in reaching cancer hospitals pose significant barriers to undergoing breast-conserving surgery (BCS), especially for cases of early-stage breast cancer.[15] Moreover, the increasing popularity of screening mammography in these regions could lead to a greater detection rate of conditions that make breast-conserving surgery unsuitable, such as multicentric lesions,[16] which accounts for 20-30%[17] of breast cancer cases identified by mammography or MRI breast. Therefore, most patients in these regions choose mastectomy as their preferred treatment.

The literature review discussed above predominantly focuses on studies from cancer centers or advanced institutions with abundant resources, in contrast to rural cancer hospitals in Thailand. These rural hospitals often depend on a single technique–using blue dye for sentinel lymph node biopsy–and lack the pathologists required for intraoperative frozen section consultations. Consequently, they must wait for permanent section pathological results. Research by Treeratanapun, N. et al. at King Chulalongkorn Memorial Hospital has shown that, in cases where patients are preoperatively clinically node-negative, the outcomes of node staging from permanent sections are comparable to those from frozen sections.[18]

The development of the single incision technique for mastectomy and BCS combined with sentinel lymph node biopsy (SLNB) originated from the traditional approach of using separate incisions for these procedures. Typically, surgeons would perform the SLNB at the axillary site first, followed by the mastectomy. This sequence was driven by the critical timing, or "golden period," associated with

Isosulfan Blue and Indocyanine Green. These tracers must be removed within 5 to 15 minutes post-injection,[19,20] as they rapidly travel through the lymphatic ducts to the sentinel node. If the SLNB is performed too early, the tracer may not have reached the sentinel node, resulting in a failure to identify it. Conversely, if the procedure is delayed, the tracer might spread to non-sentinel nodes, increasing the false-negative rate.

The single incision technique was developed to solve the limitations of the separate incision approach. Technically, the traditional technique involves making a direct incision over the axilla region to enter the cavipectoral fascia. However, if a small incision is made, it can compromise the adequacy of identifying the sentinel node. Additionally, if a catastrophic situation occurs, such as massive bleeding from a large vessel, it becomes difficult to control and handle it. By using a single incision, a large incision and clear visualization of the tissue and vessel in that area may facilitate the safe and accurate detection of the sentinel lymph node.

It not only reduces the number of incisions at the axillary site, but it also diminishes the discomfort associated with axillary incisions, which, although minor, can significantly affect the patient's daily life. Approximately 30% of patients experience chronic pain or numbness at the axillary site following an SLNB. Moreover, separate incisions can increase operative time, the risk of postoperative infection, and the incidence of seroma formation in the axillary region.[13,21,22] The primary objective of this study is to compare the efficacy of sentinel node biopsy, focusing on the number of nodes harvested, between two techniques: single incision versus separate incision. The secondary objective is to assess additional indicators of success in sentinel node biopsy between the two techniques, including identification rate, surgical outcomes, associated complications, and short-term survival outcomes in terms of overall and progression-free survival.

Materials and Methods

This retrospective cohort study was conducted at Ubonratchathani Cancer Hospital between 2020 and 2024. The inclusion criteria consisted of early-stage breast cancer patients with clinically node-negative status, as determined by physical examination and preoperative imaging (clinical stage I-II based on the 7th edition of the AJCC staging criteria). The exclusion criteria included patients with biopsy-confirmed axillary node metastasis, those who received neoadjuvant chemotherapy, and individuals with bilateral breast cancer. A total of 60 patients were initially included, but one was excluded due to a history of neoadjuvant chemotherapy, resulting in a final sample size of 59 patients. The cohort was divided into 31 patients in the single-incision group and 28 in the separate-incision group. The procedures for both groups were performed by a single surgeon who had achieved the learning curve criteria for proficiency in SNBx, which included a localization rate of $\geq 90\%$ and a false-negative rate of $\leq 5\%$. Clinical data were collected, including age, BMI, comorbidities, tumor characteristics, surgical approach, and complications. Survival outcomes were reported with median follow-up time and Kaplan-Meier curves for overall and progression-free survival. The primary outcome was lymph node yield, while secondary outcomes included operative time (time from incision to wound closure), node positivity, blood loss (overall blood loss), and complications such as seroma, wound infection, and hematoma. Additionally, survival outcomes were presented as 2-year overall survival and 2-year progression-free survival.

Descriptive statistics were used to summarize baseline characteristics and outcomes for both groups. Independent t-tests, Mann-Whitney U tests, chi-square tests, and Fisher's exact tests were performed for group comparisons. Survival outcomes were compared using the log-rank test. Univariable and multivariable regression analyses assessed factors affecting node harvesting. Generalized Linear Models (Poisson distribution) estimated incidence rate ratios (IRR) for node harvesting, while a gamma family model analyzed skewed continuous data, such as operative time and blood loss. Variables with $p < 0.05$ were retained. Model fit was evaluated using the Akaike Information Criterion (AIC) and log-likelihood ratio tests. Analyses were performed using Stata 18. The study was approved by the Ethics Committee of Ubonratchathani Cancer Hospital under protocol number EC 021/2024.

Sentinel Lymph Node Biopsy Procedure

Anesthesia and Preparation: The procedure begins with administering general anesthesia and administering prophylactic antibiotics to prevent surgical site infection.

Patient Positioning: The patient is positioned supine with the arm on the surgical side abducted to 90

degrees. A small cushion is placed under the shoulder, arm, and back to provide support.

Skin Preparation: The surgical site is thoroughly cleansed, and the area is draped to maintain a sterile field.

Injection of Tracers: Isosulfan blue dye is injected into the periductal area at 3 and 9 o'clock positions, with a subdermal injection of 2 milliliters on each side. The breast is massaged for approximately 5 minutes until the skin over the breast and axilla shows a blue discoloration, as shown in Figures 1A, 1B, and 1C.[23]

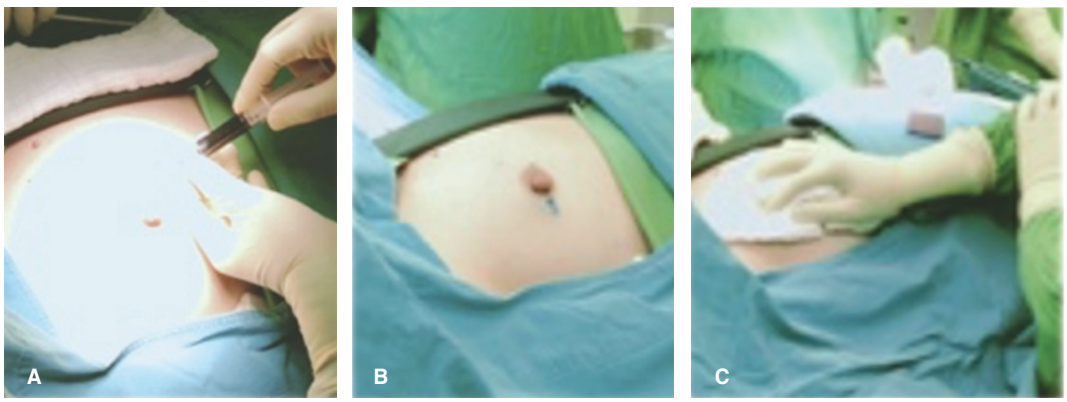

Figure 1

Incision Techniques

Separate Incisions: In cases where separate incisions are made, the axillary incision is placed at the lowest hairline, approximately 2 fingerbreadths from the axillary crease, with a length of 4-5 centimeters, as shown in Figure 2D.[23]

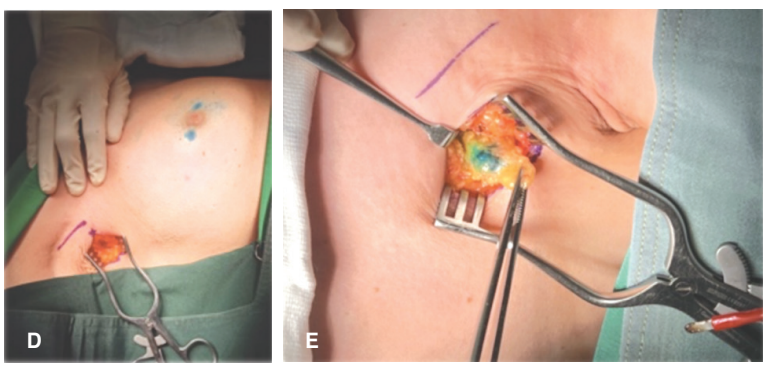

Figure 2

Single Incision: If a single incision is used, the breast incision is made first, starting at the upper outer quadrant, approximately 10 cm, to facilitate dissection toward the axilla, as shown in Figures 3F, 3G, and 3H.

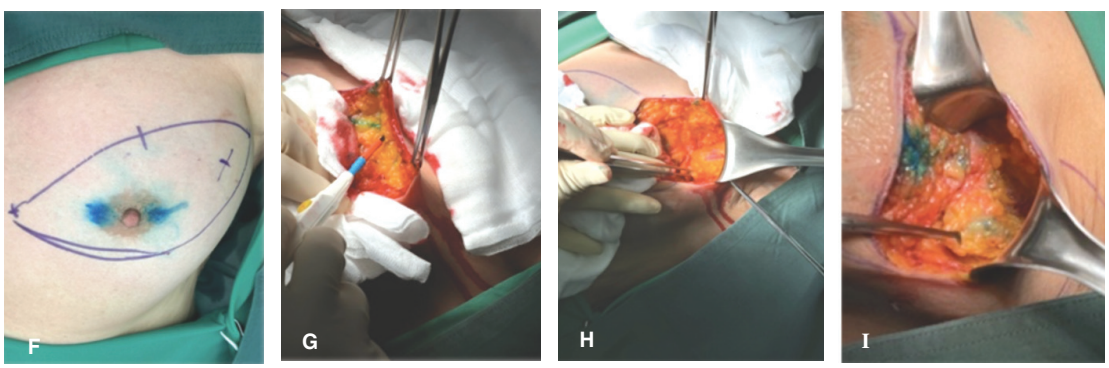

Figure 3

Dissection: After making the incision, the dissection proceeds through the subcutaneous tissue down to the axillary fascia. Upon reaching this layer, the dyed lymphatic vessels are identified and followed to locate the sentinel lymph node, as shown in Figures 2E and 3I. If the dyed lymphatic vessels are not clearly visible, anatomical landmarks, such as the edge of the pectoralis major muscle, are used to locate the sentinel lymph node.

Node Removal: Typically, 2-4 lymph nodes are excised. If an enlarged lymph node that is not stained is detected, it should also be removed.

Further Dissection: If the sentinel lymph node cannot be identified or the lymph nodes are not stained, an axillary lymph node dissection should be performed.

Breast surgery: After the removal of the sentinel lymph node, the breast operation was performed according to the planned procedure, either mastectomy or breast-conserving surgery.

RESULTS

Patient Characteristics

In Table 1, there were no statistically significant differences between the two groups in terms of age, BMI, comorbidities, tumor size, tumor side, multifocality, T stage, N stage, AJCC stage, histologic type, lymphovascular invasion (LVI), ER status, PR status, HER2 status, and tumor subtype. The surgical approach showed a significant difference between the groups, with a higher proportion of mastectomies in the single-incision group (96.77%) compared to the separate-incision group (32.14%) ($p < 0.001$). Tumors in the upper outer quadrant (UOQ) were more frequent in the separate-incision group (64.29%) than in the single-incision group (38.71%) ($p = 0.052$). Histologic Grade 1 tumors were more common in the separate-incision group (40.00%) compared to the single-incision group (17.24%) ($p = 0.089$).

Table 1 Clinical and pathological characteristics

Clinical Characteristics	Full cohort				*p*-value	Subgroup: Mastectomy				*p*-value
	Single incision N = 31		Separate incision N = 28			Single incision N = 30		Separate incision N = 9		
Age (Mean ± SD) year	53.71	± 11.32	54.21	± 12.70	0.872	54.03	± 11.37	61.11	± 11.77	0.113
Body mass index (BMI)	23.91	± 4.17	23.55	± 3.53	0.726	24.12	± 0.74	22.97	± 1.53	0.473
Comorbidity										
Yes	17	54.84%	10	35.71%	0.141	19	63.33%	5	55.56%	0.674
No	14	45.16%	18	64.29%		11	36.67%	4	44.44%	
Tumor size (Mean ± SD) cm	2.05	± 1.95	1.93	± 1.06	0.77	2.07	± 1.98	2.03	± 1.30	0.964
Surgical approach										
Mastectomy	30	96.77%	9	32.14%	< 0.001					
Breast-conserving surgery	1	3.23%	19	67.86%						
Biopsy type										
Core needle biopsy	25	80.65%	22	78.57%	0.843	25	83.33%	6	66.67%	0.277
Excision	6	19.35%	6	21.43%		5	16.67%	3	33.33%	
Side										
Right	12	38.71%	12	42.86%	0.746	12	40.00%	3	33.33%	0.718
Left	19	61.29%	16	57.14%		18	60.00%	6	66.67%	
Multifocal										
Yes	5	16.13%	2	7.41%	0.309	5	16.67%	0	0%	0.088
No	26	83.87%	25	92.59%		25	83.33%	8	88.89%	

Table 1 (cont.) Clinical and pathological characteristics

Clinical Characteristics	Full cohort				*p*-value	Subgroup: Mastectomy				*p*-value
	Single incision N = 31		Separate incision N = 28			Single incision N = 30		Separate incision N = 9		
Location: Quadrant (n, %)										
UOQ	12	38.71%	18	64.29%	0.052	11	36.67%	7	77.78%	0.184
UIQ	6	19.35%	1	3.57%		6	20.00%	0	0%	
LOQ	2	6.45%	5	17.86%		2	6.67%	1	11.11%	
LIQ	4	12.90%	2	7.14%		4	13.33%	0	0%	
Central quadrant	7	22.58%	2	7.14%		7	23.33%	1	11.11%	
T stage (n, %)										
T0	5	16.13%	4	14.29%	0.766	5	16.67%	1	11.11%	0.918
T1	16	51.61%	14	50.00%		15	50.00%	5	55.56%	
T2	9	29.03%	10	35.71%		9	30.00%	3	33.33%	
T3	1	3.23%	0	0.00%		1	3.33%	0	0%	
Node stage (n, %)										
N0	24	77.42%	23	82.14%	0.647	24	80.00%	7	77.78%	0.901
N1	4	12.90%	14	14.29%		4	13.33%	1	11.11%	
N2	3	9.68%	1	3.57%		2	6.67%	1	11.11%	
AJCC stage (n, %)										
0	6	19.35%	4	14.29%	0.776	6	20.00%	1	11.11%	0.870
1A	12	38.71%	12	42.86%		12	40.00%	5	55.56%	
2A	7	22.58%	9	32.14%		7	23.33%	1	11.11%	
2B	2	6.45%	2	7.14%		2	6.67%	1	11.11%	
3A	3	9.68%	1	3.57%		2	6.67%	1	11.11%	
4	1	3.23%	0	0.00%		1	3.33%	0	0.00%	
Pathological report (n, %)										
IDC	6	19.35%	7	25.00%	0.384	6	20.00%	4	44.44%	0.114
DCIS	5	16.13%	3	10.71%		5	16.67%	0	0%	
IDC with DCIS	17	54.84%	13	46.43%		16	53.33%	4	44.44%	
ILC	3	9.68%	2	7.14%		3	10.00%	0	0%	
Other	0	0.00%	3	10.71%		0	0%	1	11.11%	
LVI (n, %)										
Yes	11	40.47%	6	27.27%	0.325	10	33.33%	2	22.22%	0.770
No	16	59.26%	16	72.73%		16	53.33%	6	66.67%	
Histologic Grade (n, %)										
1	5	17.24%	10	40.00%	0.089	5	17.86%	4	50.00%	0.084
2	20	68.97%	10	40.00%		19	67.86%	2	25.00%	
3	4	13.79%	5	20.00%		4	14.29%	2	25.00%	

Table 1 (cont.) Clinical and pathological characteristics

Clinical Characteristics	Full cohort				*p*-value	Subgroup: Mastectomy				*p*-value
	Single incision N = 31		Separate incision N = 28			Single incision N = 30		Separate incision N = 9		
ER status (n, %)										
Negative	11	35.48%	5	19.23%	0.174	11	36.67%	2	22.22%	0.151
Positive	20	64.52%	21	80.77%		19	63.33%	6	66.67%	
PR status (n, %)										
Negative	15	48.39%	9	34.62%	0.294	15	50.00%	4	44.44%	0.181
Positive	16	51.61%	17	65.38%		15	50.00%	4	44.44%	
HER2 status (n, %)										
Negative	23	82.14%	19	79.17%	0.786	22	73.33%	6	66.67%	0.918
Positive	5	17.86%	5	20.83%		5	16.67%	2	22.22%	
Subtype (n, %)										
Luminal A	17	54.84%	19	67.86%	0.448	16	53.33%	5	55.56%	0.494
Luminal B HER-2 -	1	3.23%	0	0.00%		1	3.33%	0	0%	
Luminal B HER-2 +	1	3.23%	1	3.57%		1	3.33%	0	0%	
HER2+/neu	4	12.90%	4	14.29%		4	13.33%	2	22.22%	
Triple-negative	6	19.35%	1	3.57%		6	20.00%	0	0%	
Unknown	2	6.45%	3	10.71%		2	6.67%	2	22.22%	

UOQ = Upper outer quadrant, UIQ = Upper inner quadrant, LOQ = Lower outer quadrant, LIQ = Lower inner quadrant, IDC = Invasive ductal carcinoma, DCIS = Ductal carcinoma in situ, ILC = invasive lobular carcinoma, LVI = lymphovascular invasion, ER = Estrogen Receptor, PR = Progesterone Receptor, HER2 = Human Epidermal Growth Factor Receptor 2.

Node harvesting, surgical outcomes, and complications

The single-incision group had a significantly higher number of lymph nodes harvested compared to the separate-incision group. The median number of nodes harvested was 6 (IQR: 4–8) in the single-incision group compared to 3 (IQR: 2–6) in the separate-incision group, with a statistically significant difference ($p < 0.001$). The overall complication rates, including seroma, wound infection, and hematoma, were comparable between both groups. Partial wound dehiscence was slightly more common in the single-incision group (6.45% vs. 0%) but was not statistically significant. The safety profiles of both techniques were comparable, as shown in Table 2.

Table 2 Surgical outcomes (full cohort)

Outcome	Single incision N = 31		Separate incision N = 28		Co-efficiency	95% CI	*P*-value
Pathological outcome							
Node harvesting (Median, IQR)##	6	(4,8)	3	(2,6)	1.49*	(1.20, 1.84)	**< 0.001**
Node positive (Median, IQR)	0	(0,0)	0	(0,0)	1.35*	(0.65, 2.81)	0.415
Sentinel lymph node biopsy							
Identified	29	93.55%	26	92.86%	1.12	(0.15, 8.49)	0.916
Unidentified	2	6.45%	2	7.14%	ref	ref	
Reoperation							
Yes	2	6.45%	4	14.29%	0.41	(0.07, 2.46)	0.332
No	29	93.55%	24	85.71%	ref	ref	
Surgical outcome							
Operative time (Median) hr.	1.75	(1.25, 1.75)	2	(1.30, 2.50)	0.83**	(0.71, 0.96)	**0.011**
Blood loss (Median) cc	20	(10, 20)	20	(17.5, 50)	0.74**	(0.50, 1.10)	0.134
LOS (Median) day	4	(3, 5)	3.5	(3, 5)	0.96**	(0.79, 1.17)	0.661
Complication							
Seroma	3	9.68%	4	14.29%	0.64	(0.13, 3.16)	0.587
Partial wound dehiscence###	2	6.45%	0	0.00%	4.83	(0.22, 105.07)	0.316
Wound infection	1	3.23%	1	3.57%	0.9	(0.05, 15.10)	0.942
Hematoma or ecchymosis	4	12.90%	2	7.14%	1.92	(0.32, 11.43)	0.471
Survival Outcome***							
Median follow-up time (month)	7.1	(2.6,15.2)	10.9	(4.2, 28.9)	-	-	-
Median survival time (month)	N/A	-	N/A	-	-	-	-
Median progression survival time (month)	N/A	-	N/A	-	-	-	-
2 years OS (%, 95% CI)	94.74%	(68.12%, 99.24%)	100%	-	-	-	-
2 years PFS (%, 95% CI)	94.74%	(68.12%, 99.24%)	92.31%	(56.64%, 98.88%)	-	-	-

LOS = Length of hospital stay. A p-value of < 0.05 is considered statistically significant. Reference categories (ref) indicate the baseline comparison group for categorical variables.

The count of harvested nodes includes only the sentinel lymph nodes from the initial operation. However, in cases where the sentinel nodes were not identified during the initial procedure, all nodes harvested during that operation are included in the total count. For patients who underwent reoperation, any additional nodes harvested in the subsequent procedure were excluded from the overall node count.

* Coefficient values for node harvesting and node positivity are incidence rate ratios (IRR) derived from a Poisson generalized linear model (GLM).

The coefficiency (odds ratio) for partial wound dehiscence was calculated using Firth's penalized likelihood logistic regression due to the presence of a zero event in one group.

** Coefficients for operative time, blood loss, and length of stay (LOS) are IRRs obtained from a Gamma GLM.

*** Due to the limited number of events, presenting descriptive results may be more informative than performing a Cox regression analysis.

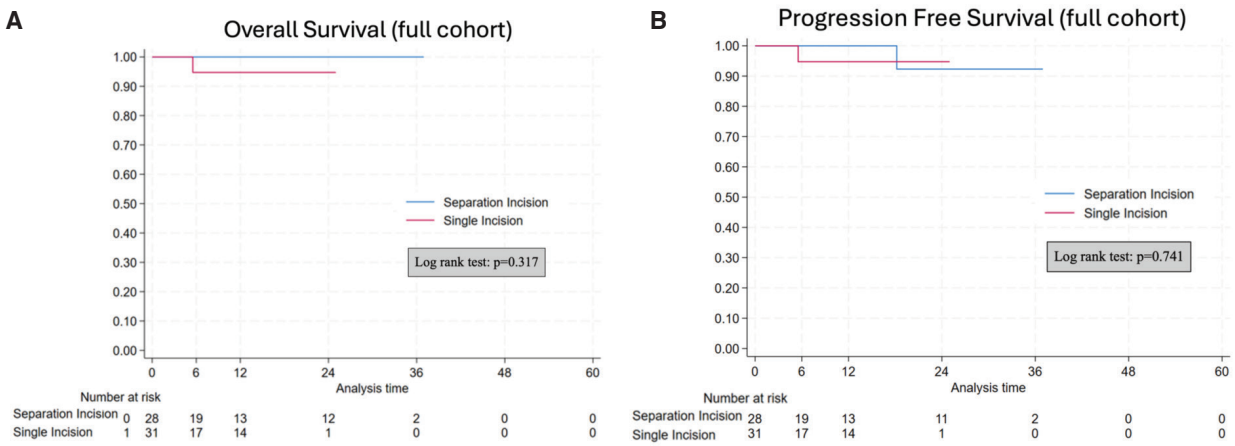

Figure 4 A: Overall Survival (full cohort)
B: Progression Free Survival (full cohort)

Survival outcome

The Kaplan-Meier survival curves for the full cohort show no significant differences in overall survival (OS) and progression-free survival (PFS) between the single-incision and separate-incision groups. The median follow-up time was longer in the separate-incision group (10.9 months, IQR 4.2–28.9) compared to 7.1 months (IQR 2.6–15.2) in the single-incision group. Two-year OS was 94.74% (95% CI: 68.12%–99.24%) for the single-incision group and 100% for the separate-incision group, with no significant difference (log-rank test, $p = 0.317$). Similarly, two-year PFS was 94.74% (95% CI: 68.12%–99.24%) and 92.31% (95% CI: 56.64%–98.88%) for the single-incision and separate-incision groups, respectively, with no significant difference (log-rank test, $p = 0.741$). These results indicate comparable survival outcomes between the two groups, as presented in Table 2, Figure 4 (A and B).

Table 3 Univariable and multivariable regression analysis for node harvesting (full cohort)

Clinical Characteristic	Univariable IRR (95% CI)	*p*-value	Multivariable IRR (95% CI)	*p*-value
Surgical Technique: Single vs. Separate Incision	1.49 (1.20-1.84)	< 0.001	1.46 (1.13-1.88)	0.003
Mastectomy vs. BCS	0.61 (0.48-0.78)	< 0.001	-	-
Age (per year increase)	0.99 (0.98-1.00)	0.058	-	-
BMI	1.03 (1.00-1.05)	0.036	-	-
Comorbidities	1.31 (1.07-1.61)	0.011	1.47 (1.17-1.85)	0.001
Biopsy type (Core needle biopsy vs excisional biopsy)	1.15 (0.90-1.48)	0.251	1.50 (1.10-2.03)	0.009
Tumor Location (UIQ)	1.68 (1.26-2.24)	< 0.001	1.70 (1.23-2.34)	0.001
Tumor Location (LIQ)	1.39 (1.00-1.92)	0.05	1.71 (1.19-2.48)	0.004
HER-2	1.30 (1.01-1.67)	0.041	1.36 (1.01-1.83)	0.040
Histologic Grade (3 vs. 1)	1.78 (1.29-2.46)	< 0.001	1.66 (1.23-2.23)	0.001

BCS = Breast conserving surgery, UIQ = Upper inner quadrant, LIQ = Lower inner quadrant, IRR = Incidence rate ratios

In Table 3, the single-incision technique is associated with a 46% higher likelihood of node harvesting compared to the separate-incision technique [IRR = 1.46, 95% CI (1.13-1.88), $p = 0.003$] even after adjusting for other clinical factors. Other factors independently associated with increased node yield include comorbidities (IRR = 1.47, $p = 0.001$), biopsy type (IRR = 1.50, $p = 0.009$), tumor location in the UIQ (IRR = 1.68, $p = 0.001$) and LIQ

(IRR = 1.71, $p = 0.004$), HER-2 positivity (IRR = 1.36, $p = 0.040$), and higher histologic grade (IRR = 1.66, $p = 0.001$). Age, BMI, and surgical approach (mastectomy vs. BCS) were insignificant after adjusting for other variables in the multivariable model.

Subgroup analysis

Patient Characteristics

In Table 1, In the mastectomy subgroup (N = 39), the mean age was higher in the separate incision group (61.11 vs. 54.03 years, $p = 0.113$), though not statistically significant. Tumor size was similar between the groups (2.03 vs. 2.07 cm, $p = 0.964$). Tumor location in the upper outer quadrant (UOQ) was more frequent in the separate incision group (77.78% vs. 36.67%, $p = 0.184$). There was a trend toward more Grade 1 tumors in the separate incision group (50% vs. 17.86%, $p = 0.084$). Subtype distribution showed no significant differences, with Luminal A being the most common subtype (55.56% vs. 53.33%, $p = 0.494$). Other clinical characteristics, including comorbidities, biopsy type, node status, and receptor status, showed no significant differences.

Node harvesting, surgical outcomes, complications

The single-incision group had a median of 6 nodes harvested (IQR 4–8) compared to 5 (IQR 2–10) in the separate-incision group, with no significant difference ($p = 0.239$). Sentinel lymph node biopsy identification rates were high in both groups (90% vs. 100%, $p = 0.571$). Operative time was significantly shorter in the single-incision group (1.75 hours vs. 2.5 hours, $p < 0.001$). Other outcomes, including reoperation rates, blood loss, length of stay, and complications, showed no significant differences between the groups, as presented in Table 4.

Table 4 Surgical outcomes (mastectomy subgroup)

Outcome	Single incision N = 30		Separate incision N = 9		Co-efficiency	95% CI	*P*-value
Pathological outcome							
Node harvesting (Median, IQR)##	6	(4,8)	5	(2, 10)	1.19	(0.89, 1.61)	0.239
Node positive (Median, IQR)	0	(0,0)	0	(0, 0)	0.7	(0.27, 1.82)	0.465
Sentinel lymph node biopsy							
Identified	27	90.00%	9	100.00%	0.41	(0.12, 8.76)	0.571
Unidentified	3	10.00%	0	0%	ref	ref	
Reoperation**							
Yes	2	6.67%	0	0%	1.67	(0.07, 37.89)	0.749
No	28	93.33%	100	100%	ref	ref	
Surgical outcome							
Operative time (Median) hr.	1.75	(1.25, 1.75)	2.5	(2, 2.5)	0.69**	(0.59, 0.82)	**< 0.001**
Blood loss (Median) cc	20	(10, 20)	20	(20, 50)	0.69**	(0.38, 1.25)	0.225
LOS (Median) day	4	(3, 4)	5	(3, 6)	0.84**	(0.63, 1.11)	0.219
Complication							
Seroma	2	6.67%	1	11.11%	0.57	(0.05, 7.14)	0.664
Partial wound dehiscence###	2	6.67%	0	0%	1.67	(0.07, 37.89)	0.749
Wound infection	1	3.33%	0	0%	0.97	(0.04, 25.75)	0.984
Hematoma or ecchymosis	4	13.33%	1	11.11%	1.23	(0.12, 12.65)	0.861
Survival Outcome**							
Median follow-up time (month)	7	(2.6, 14.4)	30.8	(28.8, 34.5)	-	-	-
Median survival time (month)		N/A		N/A	-	-	-
Median progression survival time (month)		N/A		N/A	-	-	-
2 years OS (%, 95%CI)	94.44%	(66.64%, 99.20%)	100%	-	-	-	-
2 years PFS (%, 95%CI)	94.44%	(66.64%, 99.20%)	87.50%	(38.70%, 98.14%)	-	-	-

A p-value of < 0.05 is considered statistically significant. Reference categories (ref) indicate the baseline comparison group for categorical variables.

The count of harvested nodes includes only the sentinel lymph nodes from the initial operation. However, in cases where the sentinel nodes were not identified during the initial procedure, all nodes harvested during that operation are included in the total count. For patients who underwent reoperation, any additional nodes harvested in the subsequent procedure were excluded from the overall node count.

The coefficiency (odds ratio) for partial wound dehiscence was calculated using Firth's penalized likelihood logistic regression due to the presence of a zero event in one group.

* Coefficient values for node harvesting and node positivity are incidence rate ratios (IRR) derived from a Poisson generalized linear model (GLM).

** Coefficients for operative time, blood loss, and length of stay (LOS) are IRRs obtained from a Gamma GLM.

*** Due to statistical reasons, Firth's logistic regression was used instead of standard logistic regression to address the issue of perfect prediction.

**** Due to the limited number of events, presenting descriptive results may be more informative than performing a Cox regression analysis.

Survival outcome

The Kaplan-Meier curves for overall survival (OS) and progression-free survival (PFS) in the mastectomy subgroup show no significant differences between the single-incision and separate-incision groups. The median follow-up time was longer in the separate-incision group (30.8 vs. 7 months). Two-year OS was 94.44% for the single-incision group and 100% for the separate-incision group, with the log-rank test indicating no significant difference ($p = 0.480$). Similarly, two-year PFS was 94.44% and 87.50%, respectively, with no significant difference ($p = 0.940$). These findings suggest that survival outcomes are comparable regardless of surgical technique, as shown in Table 4, Figures 5 (A and B).

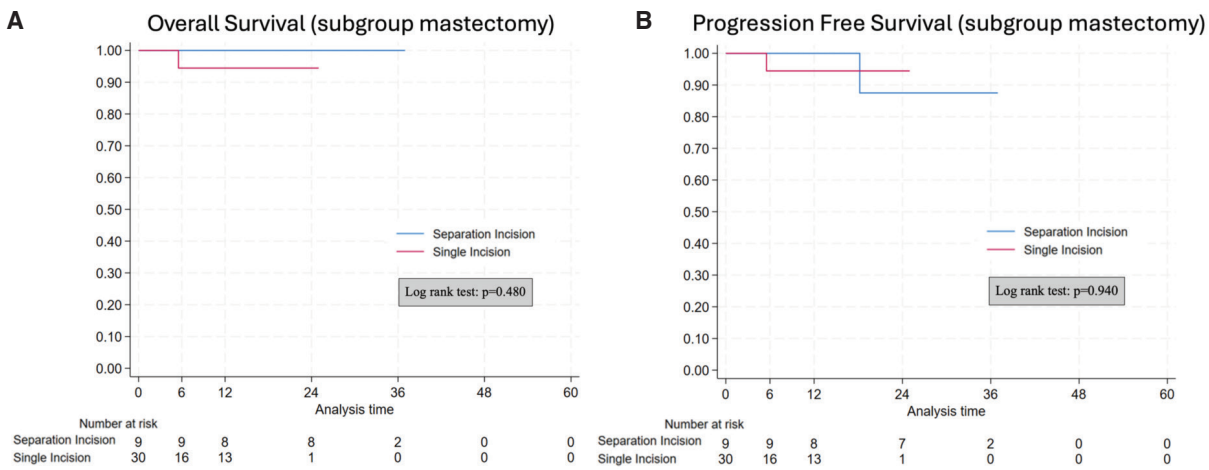

Figure 5 A: Overall Survival (subgroup mastectomy)
B: Progression Free Survival (subgroup mastectomy)

Table 5 Univariable and multivariable regression analysis for node harvesting (mastectomy subgroup)

Clinical Characteristic	Univariable		Multivariable	
	IRR (95% CI)	*p*-value	IRR (95% CI)	*p*-value
Surgical Technique: Single vs. Separate Incision	1.19 (0.89-1.60)	0.239	1.40 (1.00-1.95)	0.050
Age (per year increase)	0.99 (0.98-1.00)	0.043	-	-
BMI	1.03 (1.00-1.05)	0.048	1.05 (1.02, 1.09)	< 0.001
Tumor size	1.05 (0.99,1.12)	0.116	1.14 (1.06, 1.22)	< 0.001
Tumor Location (UIQ)	1.61 (1.21-2.13)	0.001	-	-
Tumor Location (LOQ)	1.58 (1.18,2.12)	0.002	-	-
Tumor Location (Central)	1.37 (0.97,1.93)	0.078	2.34 (1.54, 3.56)	< 0.001
LVI	0.93 (0.71,1.20)	0.572	0.51 (0.37, 0.70)	< 0.001
HER-2	1.08 (0.80-1.45)	0.619	-	-
Histologic Grade (3 vs. 1)	1.35 (1.00-1.82)	0.049	3.13 (2.09-4.67)	< 0.001

BCS = Breast conserving surgery, UIQ = Upper inner quadrant, LIQ = Lower inner quadrant, IRR = Incidence rate ratios

In Table 5, the single-incision technique is associated with a 40% higher likelihood of node harvesting compared to the separate-incision technique [IRR = 1.40, 95% CI (1.00–1.95), $p = 0.050$] after adjusting for other clinical factors. Other factors independently associated with increased node yield include BMI (IRR = 1.05, $p < 0.001$), tumor size (IRR = 1.14, $p < 0.001$), central tumor location (IRR = 2.34, $p < 0.001$), and higher histologic grade (Grade 3 vs. Grade 1, IRR = 3.13, $p < 0.001$). Lymphovascular invasion (LVI) was inversely associated with node yield (IRR = 0.51, $p < 0.001$). Age, HER-2 status, and tumors located in the UIQ and LOQ did not remain significant after adjusting for other variables in the multivariable model.

Discussion

This pilot study comparing the single-incision and separate-incision techniques for sentinel lymph node biopsy (SLNB) in breast cancer patients provides important insights into surgical outcomes, particularly in relation to lymph node harvesting. The single-incision technique demonstrated a 46% increase in the number of harvested lymph nodes compared to the separate-incision approach in both mastectomy and breast-conserving surgery (BCS) groups. Additionally, there was a 40% increase in lymph node yield with the single-incision technique compared to the separate-incision approach within the mastectomy subgroup. This increase in node yield may result from better access and visualization of the axillary nodes through a single incision, facilitating easier identification and removal of sentinel nodes. Moreover, the shorter operative time, particularly in the mastectomy subgroup associated with the single-incision technique, indicates improved surgical efficiency, potentially lowering the risk of complications and shortening recovery periods. The sentinel node identification rate using the single-dye technique, without a frozen section, is comparable to findings from other studies, achieving a 93% identification rate for the full cohort and 90% for the mastectomy subgroup with a single incision. These results did not show a statistically significant difference compared to the standard separate-incision technique. The safety profiles of both techniques were similar, with no significant differences observed in complications such as seroma formation, wound infections, or hematoma. However, partial wound dehiscence occurred more frequently in the single-incision group. Also, the survival outcomes, in terms of overall survival and progression-free survival, were comparable between both surgical techniques for the full cohort and the mastectomy subgroup.

Lovasik et al. (2018), in a study conducted at a tertiary academic cancer center in the United States with a sample size of 110 patients, demonstrated the benefits of the single-incision technique, showing a 12.5% reduction in operative time. However, there was no difference in node harvesting for early breast cancer patients. The number of identified nodes in their study was significantly lower for the single-incision group compared to the separate-incision group (Median [IQR] = 2[2,3], $p = 0.05$). Despite a 100% identification rate of sentinel nodes with the single tracer technique, the study's focus on breast-conserving surgery (BCS) for upper outer quadrant (UOQ) tumors likely limited visualization through a single incision. The study also reported comparable complication rates between the two techniques. Zhang et al. (2021), in a study conducted in China using advanced technology, focused on early breast cancer patients undergoing mastectomy and compared single-incision and separate-incision techniques for sentinel lymph node biopsy using a dual-tracer approach. The single-incision technique resulted in a higher median number of harvested nodes (3.2 ± 1.1 nodes in the single-incision group compared to 2.7 ± 1.0 nodes in the separate-incision group; $p = 0.001$), as well as a reduction in operative time and a decreased rate of upper limb numbness. Other complications and recurrence rates were comparable between the two groups.

The selection of techniques in this study was influenced by certain aspects of surgeon preference, introducing a potential selection bias. This bias arises because the technique provides easier access to the axillary region and facilitates sentinel lymph node identification, making it the preferred approach once the surgeon's learning curve stabilizes. For mastectomy patients, the criteria for choosing the single-incision technique included younger age and smaller breast size. For patients undergoing breast-conserving surgery (BCS), the single-incision technique was primarily selected for tumors located in the upper outer quadrant (UOQ). The separate-incision technique remains relevant for specific patient subgroups and tumor characteristics, particularly in cases of non-UOQ tumors, reoperations following mastectomy, and patients with high BMI. Veronesi et al. (2003) suggest that sentinel lymph nodes should be removed through the same incision for UOQ tumors, while a separate incision is recommended for non-UOQ tumors,[24] as it provides easier direct access to the nodes. This is especially important in oncoplastic surgery, where cosmetic outcomes are a concern.[25] Furthermore, in patients with high BMI, the higher failure rate of sentinel lymph node mapping[26] increases the likelihood of needing a complete axillary lymph node dissection, for which a direct axillary incision may facilitate easier dissection. The single-incision technique allows for better visualization due to its similarity to the approach used in modified radical mastectomy, a procedure familiar to most surgeons. This familiarity aids in identifying anatomical landmarks such as the clavipectoral fascia and pectoralis major. The technique also provides clear visualization of the blue-stained sentinel lymph node or the lymphatic tract originating from the

injection site, enabling precise identification and removal of sentinel nodes. The single-incision technique is associated with a shorter operative time due to the need to suture only one incision. Postoperative complications such as seroma and ecchymosis were less common in the single-incision group, likely due to the wider surgical field, facilitating more efficient hemostasis. Also, the placement of a surgical drain covering both the axilla and the mastectomy wound is more efficient when these areas are treated as a single unit, leading to a reduced incidence of postoperative seroma. In terms of infection, the separate incision technique, with one incision located in the axillary region, is more prone to infection, partly due to the difficulty of adequate postoperative dressing in that area. Combining both incisions into a single wound reduces the risk of infectious complications. Lymph node harvesting is a critical factor in lymph node staging. While it is generally recommended to excise 2-4 sentinel nodes, some studies suggest that removing up to five nodes ensures the detection of metastatic nodes in over 99% of patients.[27] The number of excised nodes plays a key role in determining adjuvant treatment, influencing decisions about chemotherapy, its duration, and postoperative radiation therapy, including the radiation field and dose. A shorter operative time is especially beneficial in resource-limited settings, as it minimizes patients' exposure to general anesthesia and reduces the risk of complications such as infection, bleeding, and wound healing issues.[28] A study of the ACOSOG Z0011 trial with a 10-year follow-up of sentinel lymph node biopsy in patients who underwent breast-conserving surgery (BCS) reported a median follow-up time of 9.25 years. The cumulative incidence of locoregional recurrence was 3.8% at 10 years.[29] Another study demonstrated a 5-year survival rate of 94% (95% CI, 91%–97%) in patients who underwent dual-dye and separate-incision techniques for sentinel lymph node biopsy. However, this study had a prolonged follow-up period, with a minimum follow-up time of 5 years.[30] Although survival analysis of our current dataset showed no significant difference in survival outcomes between the two techniques, its interpretation is limited by the small number of events and the short follow-up duration, capturing only 2-year overall survival and progression-free survival.

This comparative study design is particularly relevant to real-world applications, especially in resource-limited centers that utilize a single-dye technique for sentinel lymph node biopsy without the availability of frozen section analysis. The single-incision technique has the potential to be incorporated into standard practices at such institutions. The study also employs multivariable analysis, using a generalized linear model (Poisson regression), to isolate the specific impact of the single-incision technique on node harvesting. This approach allows for controlling confounding variables and comprehensively analyzes the factors affecting node harvest. However, the study has several limitations. First, the sample size is relatively small, reflecting the limited annual case volume at the institute, making it smaller than comparable studies. Second, the lack of randomization is a limitation, partly due to the novelty of this technique in Thailand, which raises ethical concerns regarding randomization. Third, the study is confined to a single center and was performed by one surgeon, which may limit the generalizability of the findings to other settings. Surgeons in different institutions may also require a learning curve to perform the procedure effectively, which could influence the outcomes. The short follow-up period is also a notable limitation, as it prevents evaluating long-term survival outcomes.

Future research should focus on larger sample sizes and employ prospective, multicenter randomized controlled trials to validate the outcomes of the single-incision technique and improve the generalizability of findings. In addition, future research should analyze long-term oncological outcomes such as overall survival and recurrence-free survival. Incorporating cosmetic outcomes and quality-of-life assessments would provide valuable insights into the broader impact of this technique on patient satisfaction.

Conclusion

The single-incision technique for sentinel lymph node biopsy demonstrates significant advantages in node harvesting and surgical efficiency compared to the separate-incision method, as observed in both the full cohort and the mastectomy subgroup. This approach results in a 46% increase in node yield for the full cohort, a 40% increase for mastectomies, and reduced operative time. Moreover, complication rates are comparable to those of the separate-incision method, making the single-incision technique a viable and effective option for improving SLNB outcomes in breast cancer patients. However, the impact of increased node yields on long-term patient

outcomes remains unclear. Future research should explore whether these advantages translate into improved oncological outcomes. Randomized controlled trials with larger sample sizes and longer follow-up periods are needed to confirm these findings and provide further insights into the safety and efficacy of the single-incision technique.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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Original Article

Recurrent Rate in Rectal Cancer Patients with Clinically Suspected Lateral Pelvic Lymph Node Metastasis Following Neoadjuvant Chemoradiotherapy (CRT) and Total Mesorectal Excision (TME)

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Abstract

Background: The presence of lateral pelvic lymph node (LPLN) metastasis in rectal cancer has been associated with poor prognosis. We aimed to determine the recurrent outcome in patients with clinically suspected LPLN metastasis following neoadjuvant chemoradiotherapy (CRT) and total mesorectal excision (TME).

Materials and Methods: Rectal cancer patients who received neoadjuvant chemoradiotherapy (CRT) and total mesorectal excision (TME) between 2014 and 2023. The Patients' characteristics, LPLNs status, MRI or CT findings, operative and pathologic findings, recurrent rate, and survival rate were analyzed retrospectively.

Results: Among 131 patients, 88 were in the non-suspected group and 43 in the suspected group before CRT. After CRT, 86 patients in the non-suspected group remained non-suspected, while 2 developed newly suspected LPLN. In the suspected group, 15 patients responded to CRT, whereas 28 remained persistently suspected. The overall recurrence rate was 27.5% (36/131), including 4.6% (6/131) locoregional, 15.3% (20/131) distant, and 7.6% (10/131) both locoregional and distant recurrence.

In the non-suspected group, 25.6% (22/86) developed recurrence (local: 4.7%, distant: 16.3%, both: 4.7%), while both patients (100%) in the newly suspected group had recurrence involving both local and distant sites.

In the suspected group, there were responded group, 20% (3/15) had recurrence (distant: 13.3%, both: 6.7%), and in the persistently suspected group, 32.1% (9/28) had recurrence (local: 7.1%, distant: 14.3%, both: 10.7%).

The newly suspected group had significantly worse recurrence outcomes than the non-suspected group (HR = 8.95, 95% CI: 2.02–39.63; $p = 0.004$). However, there were no significant differences in recurrence rates for the responded group (HR = 1.11, $p = 0.865$) and persistently suspected group (HR = 1.23, $p = 0.607$) compared to the non-suspected group.

Post-treatment analysis revealed that LPLN location in the obturator region and unilateral involvement were significantly associated with increased locoregional recurrence risk. However, only 1 out of 16 patients with local recurrence developed lateral local recurrence.

Conclusion: Neoadjuvant chemoradiotherapy provided comparable local disease control between patients with and without clinically suspected LPLN metastasis in rectal cancer. The progression of LPLNs after CRT was a significant risk factor for recurrence compared to non-progression, highlighting the importance of post-treatment imaging in predicting oncologic outcomes.

Keywords: Lateral pelvic lymph nodes, Rectal cancer, Chemoradiotherapy, Total mesorectal excision

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Introduction

Although current treatments for locally advanced rectal cancer using chemoradiotherapy (CRT) followed by total mesorectal excision (TME) have significantly reduced the rate of local recurrence, with rates as low as 5.8–7.1%,[1-4] lymph node metastasis remains a crucial prognostic factor.[5] The theory suggests that lymph node spread in mid-to-low rectal cancer can extend laterally into the pelvic region.[6,7] Since TME surgery does not include the removal of these lateral pelvic lymph nodes (LPLN), residual cancer may remain. LPLNs involvement occurs in approximately 15–20% of patients with low-lying rectal cancer.[8] Numerous studies have indicated that such lateral lymphatic spread is a significant factor contributing to recurrence rates.[9-11]

There is a distinct difference in the treatment approaches for locally advanced rectal cancer. In Eastern regions, particularly Japan, the standard treatment involves TME with prophylactic lateral lymph node dissection (LLND) without CRT.[12-14] In contrast, in Western countries, the standard approach is CRT followed by TME without LLND[1,3,4,15] Several previous studies have suggested that both CRT combined with TME and TME combined with LLND can reduce recurrence rates with relatively comparable outcomes.[1,2,16,17] However, these methods are often insufficient to control lymph nodes in the lateral pelvic region, particularly in cases where LPLN metastasis is suspected.[9-11,16,17] It has been recommended to consider LLND selectively for patients with suspected LPLN involvement after preoperative radiation therapy, as this approach may yield the most optimal outcomes.[5,10,18-21]

It is well-known that LLND is a complex surgical procedure associated with a high rate of complications.[22-24] It is not yet widely adopted and is not currently a standard treatment recommendation. Additionally, there is no established international consensus on this matter due to differences in expertise and treatment environments,[25] underscoring the need to evaluate the advantages and disadvantages of LLND carefully. Factors such as the surgeon's experience and the risk of complications should be considered to determine the most appropriate approach for individual cases.

This study aims to clarify and evaluate the recurrence outcomes of rectal cancer patients with or without clinically suspected LPLN metastasis based on pretreatment imaging following neoadjuvant chemoradiotherapy (CRT) and total mesorectal excision (TME). The findings aim to provide insights into treatment efficacy and guide future management strategies for this high-risk patient population.

Materials and Methods

This retrospective study utilized single-center data from Rajavithi Hospital, Bangkok, Thailand, including rectal cancer patients treated with CRT followed by TME between January 2014 and December 2023. We included patients with mid-to-low rectal cancer, defined as tumors located within 10 cm of the anal verge (AV), with clinical staging of cT3/cT4 and/or node-positive disease. Patients who did not receive neoadjuvant CRT, those who underwent postoperative CRT, those with distant metastases at diagnosis, and individuals with a history of other malignancies were excluded.

Patients were categorized into two groups by suspicious lymph node based on pre-treatment imaging and further divided into four groups by lymph node responsiveness after post-treatment imaging, using criteria such as a short-axis lymph node size of ≥ 5 mm and morphological features,[26] including round shape, irregular borders, and mottled heterogeneity. All patients underwent neoadjuvant CRT, which included 50–50.4 Gy of radiation administered in 25–28 fractions with concurrent chemotherapy, followed by TME within 6–12 weeks after CRT. As mentioned above, post-CRT patients were classified into four groups based on post-treatment imaging findings: the non-suspected group, comprising patients who continued to show no malignant features after treatment; the newly suspected group, consisting of patients who developed new imaging features indicative of malignancy after CRT, despite having no concerning signs initially; the responded group, which included patients whose malignant features were controlled or reduced following CRT; and the persistently suspected group, involving patients whose malignant features remained unchanged on imaging, indicating persistent disease (Figure 1). Comprehensive demographic and clinicopathological data were collected, including age, sex, BMI, pre-operative CEA levels, tumor distance from the anus, pre-operative MRI findings, presence of EMVI, clinical and pathological staging, circumferential resection margin (CRM) involvement, and receipt of adjuvant chemotherapy.

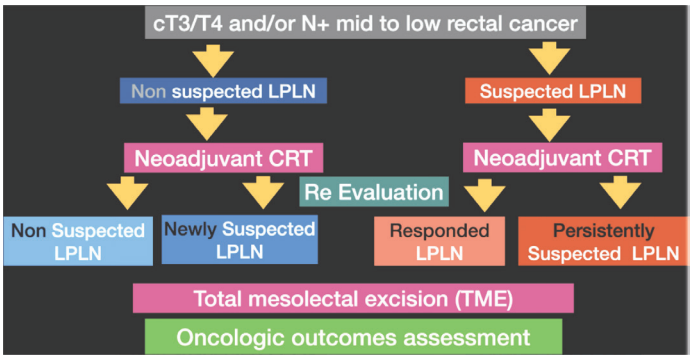

Figure 1

Our primary outcome is an overall recurrence, which refers to total tumor recurrence, including locoregional recurrence refers to the tumor recurrence within the pelvic cavity, further categorized into central and lateral recurrence based on the pelvic side wall; distant recurrence refers to tumor recurrence outside the pelvic cavity, involving distant organs or lymph nodes, Recurrence detection follows a defined protocol using computed tomography or colonoscopy findings, with the timing of recurrence measured from the date of surgery to the date of recurrence detection and recurrence-free survival (RFS) refers to the length of time after treatment during which a patient remains free from any signs or symptoms of cancer recurrence. Secondary outcomes focused on identifying specific LPLN factors, such as size, morphology, and location, that could influence the risk of locoregional recurrence in rectal cancer patients.

Statistical analysis was performed using SPSS version 29 (IBM Corporation, IL, USA). The chi-square or Fisher's exact test was used to analyze categorical data. The hazard ratio (HR) and 95% confidence interval were calculated. Where zeros caused problems with the computation of the hazard ratio, 0.5 was added to all cells. Binary logistic regression was utilized to ascertain the clinical variables linked to treatment failure, and a p-value < 0.05 was considered statistically significant.

Results

Out of a total of 131 patients who underwent CRT followed by TME, 43 patients had suspected LPLN on pre-treatment imaging, while the remaining 88 patients were categorized as non-suspected LPLN. After CRT, out of 88 patients in the non-suspected group, 86 remained non-suspected, while 2 developed newly suspected LPLN. Among the 43 suspected LPLN patients, 15 were classified as responded LPLN, and 28 as persistently suspected LPLN. Baseline characteristics are summarized in Table 1. The mean age was 57.7 ± 12.7 years in the suspected LPLN group, 60.33 ± 11.09 in the non-suspected group, 56.73 ± 12.23 in the responded group, and 58.25 ± 13.21 in the persistently suspected group. Male proportions were 62.8%, 60.2%, 46.7%, and 32.1%, respectively. Median pre-operative CEA levels were 4.22 in suspected LPLN, 5.01 in non-suspected, 4.53 in responded, and 3.47 in persistently suspected groups. The median tumor distance from the anus was 6 cm across all groups. Nearly half of the patients were evaluated by MRI: 47.7% in suspected, 46.5% in non-suspected, 46.7% in responded, and 46.4% in persistently suspected groups. Positive EMVI rates were 16.3%, 22.7%, 6.7%, and 21.4%, respectively. Most patients in all groups had clinical tumor stage cT3 (72.1% in suspected, 73.9% in non-suspected, 80% in responded, and 67.9% in persistently suspected groups). The operative approach was predominantly open or laparoscopic: 51.2% and 46.5% in suspected LPLN, 48.9% and 48.9% in non-suspected, 60% and 33.3% in responded, and 46.4% and 53.6% in persistently suspected groups. Most tumors were moderately differentiated, with rates of 74.4%, 61.4%, 73.3%, and 75% in suspected, non-suspected, responded, and persistently suspected LPLN groups, respectively. Pathological staging was predominantly ypT3 in all groups, while the pathological nodal stage was mostly ypN0: 58.1% in suspected, 65.9% in non-suspected, 53.3% in responded, and 60.7% in persistently suspected groups. Positive circumferential resection margins were low, observed in 2.3% of suspected LPLN, 5.7% of non-suspected, 6.7% of responded, and none in persistently suspected groups. A minority of patients did not receive adjuvant chemotherapy, with rates of 16.3%, 22.7%, 13.3%, and 17.9%, respectively.

Most characteristics showed no significant differences; however, ASA status was higher in persistently suspected LPLN compared to responded LPLN (p = 0.033), and clinical node stage cN2 was significantly higher in the suspected LPLN group (30.2%) compared to non-suspected LPLN (17.0%, p = 0.013), with no cN0 cases in the suspected LPLN group (Table 1).

Table 1 Demographic data

Characteristics	All patients n = 131 (100%)	Suspected LPLN n = 43 (32.8%)	Non-suspected LPLN n = 88 (67.2%)	*P*-value	Responded LPLN n = 15 (34.9%)	Persistently suspected LPLN n = 28 (65.1%)	*p*-value
Age (yr.)	59.4 (± 11.7)	57.7 (±12.7)	60.33 ± 11.09	0.242	56.73 (± 12.23)	58.25 (± 13.21)	0.715
Male (%)	80 (61.1)	27 (62.8)	53 (60.2)	0.778	7 (46.7)	9 (32.1)	0.348
BMI (kg/m²)	22.8 (± 4.1)	22.9 (± 4.2)	22.7 (± 4.1)	0.745	21.70 (± 4.09)	23.58 (± 4.15)	0.162
ASA (%)							
1	1 (0.8)	0 (0.0)	1 (1.1)		0	0	
2	69 (52.7)	25 (58.1)	45 (50.0)	0.708	12 (80)	13 (46.4)	0.033
3	59 (45.0)	18 (41.9)	41 (46.6)		3 (20)	15 (53.6)	
4	2 (1.5)	0 (0.0)	2 (2.3)		0	0	
Pre-operative CEA	4.6 (0.95-625.90)	4.22 (1.07-69.77)	5.01 (0.95-625.90)	0.296	4.53 (1.23-69.77)	3.47 (1.07-64.49)	0.665
Distance from anus (cm)	6 (0-10)	6 (1-10)	6 (0-10)	0.925	6 (1-10)	6 (1-10)	0.318
Pre-operative MRI (%)	62 (47.3)	42 (47.7)	20 (46.5)	0.896	7 (46.7)	13 (46.4)	0.988
EMVI Positive (%)	27 (20.6)	7 (16.3)	20 (22.7)	0.392	1 (6.7)	6 (21.4)	0.211
Post-treatment evaluation (wk)	7 (1-34)	7 (1-12)	7 (1-34)	0.253	8 (6-10)	7 (1-12)	0.186
Clinical staging							
cT -stage (%)				0.467			0.602
cT2	1 (0.8)	1 (2.3)	0 (0.0)		0	1 (3.6)	
cT3	96 (73.3)	31 (72.1)	65 (73.9)		12 (80)	19 (67.9)	
cT4	34 (26.0)	11 (25.6)	23 (26.1)		3 (20)	8 (28.6)	
cN-stage (%)				0.013			0.096
cN0	13 (9.9)	0 (0.0)	13 (14.8)		0	0	
cN1	90 (68.7)	30 (69.8)	60 (68.2)		13 (86.7)	17 (60.7)	
cN2	28 (21.4)	13 (30.2)	15 (17.0)		2 (13.3)	11 (39.3)	
Operative approach (%)				0.933			0.187
Open	65 (49.6)	22 (51.2)	43 (48.9)		9 (60)	13 (46.4)	
Lap	63 (48.1)	20 (46.5)	43 (48.9)		5 (33.3)	15 (53.6)	
Robotic	3 (2.3)	1 (2.3)	2 (2.3)		1 (6.7)	0	
Pathology							
Differentiation (%)				0.349			0.817
pCR	13 (9.9)	3 (7.0)	13 (14.8)		2 (13.3)	1 (3.6)	
Well	29 (22.1)	7 (16.3)	20 (22.7)		2 (13.3)	5 (17.9)	
Moderate	87 (66.4)	32 (74.4)	54 (61.4)		10 (73.3)	21 (75.0)	
Poor	2 (1.5)	1 (2.3)	1 (1.1)		0	1 (3.6)	
Pathological Staging							
ypT-stage (%)				0.666			0.572
ypT0	16 (12.2)	3 (7.0)	13 (14.8)		2 (13.3)	1 (3.6)	
ypT1	3 (2.3)	1 (2.3)	2 (23)		0	1 (2.3)	
ypT2	20 (15.3)	7 (16.3)	13 (14.8)		1 (6.7)	6 (21.4)	
ypT3	70 (53.4)	26 (60.5)	44 (50.0)		10 (66.7)	16 (57.1)	
ypT4	22 (16.8)	6 (14.0)	16 (18.2)		2 (13.3)	4 (14.3)	
ypN-stage (%)				0.685			0.672
ypN0	83 (63.4)	25 (58.1%)	58 (65.9)		8 (53.3)	17 (60.7)	
ypN1	29 (22.1)	11 (25.6)	18 (20.5)		5 (33.3)	6 (21.4)	
ypN2	19 (14.5)	7 (16.3)	12 (13.6)		2 (13.3)	5 (17.9)	
CRM positive	6 (4.6)	1 (2.3)	5 (5.7)	0.663	1 (6.7)	0	0.349
Adjuvant Chemotherapy (%)	104 (79.4)	36 (83.7)	68 (77.3)	0.392			
None	27 (20.6)	7 (16.3)	20 (22.7)	0.400	2 (13.3)	5 (17.9)	0.801
5FU	21 (16)	4 (9.3)	17 (19.3)		1 (6.7)	3 (10.7)	
Cape	11 (8.4)	5 (11.6)	6 (6.8)		1 (6.7)	4 (14.3)	
FOLFOX	38 (29)	15 (34.9)	23 (26.1)		4 (14.3)	10 (35.7)	
CapeOX	34 (26)	12 (27.9)	22 (25.0)		6 (40.0)	6 (21.4)	

Mean ± SD; Median (min-max); N (%)

Recurrence outcome

The overall recurrence rate was 27.5% (36 out of 131 patients), comprising 6 cases (4.6%) of locoregional recurrence, 20 cases (15.3%) of distant recurrence, and 10 cases (7.6%) of both locoregional and distant recurrence. Group-specific analysis revealed that in the non-suspected LPLN group, the overall recurrence rate was 25.6% (22 patients), with 4 cases (4.7%) of locoregional recurrence, 14 cases (16.3%) of distant recurrence, and 4 cases (4.7%) of both types. In the newly suspected LPLN group, the overall recurrence rate was 100% (2 patients), with both experiencing both locoregional and distant recurrences. For the responded LPLN group, the overall recurrence rate was 20% (3 patients), including 2 cases (13.3%) of distant recurrence and 1 case (6.7%) of both types of recurrence. In the persistently suspected LPLN group, the overall recurrence rate was 32.1% (9 patients), with 2 cases (7.1%) of locoregional recurrence, 4 cases (14.3%) of distant recurrence, and 3 cases (10.7%) of both locoregional and distant recurrence (Table 2).

Table 2 Recurrent rate between groups

Pre-CRT	Non-suspected LPLN n = 88 (%)		Suspected LPLN n = 43 (%)		All n = 131
Post-CRT	Non-suspected LPLN n = 86	Newly suspected LPLN n = 2	Responded LPLN n = 15	Persistently suspected LPLN n = 28	
All (%)	22 (25.6)	2 (100)	3 (20)	9 (32.1)	36 (27.5)
Locoregional (%)	4 (4.7)	0	0	2 (7.1)	6 (4.6)
Distant (%)	14 (16.3)	0	2 (13.3)	4 (14.3)	20 (15.3)
Both (%)	4 (4.7)	2 (100)	1 (6.7)	3 (10.7)	10 (7.6)

Recurrent rate n (%), CRT-Neoadjuvant chemoradiation, LPLN-Lateral pelvic lymph node

During the follow-up period, at 1 year, the recurrence rate was 5% in the non-suspected LPLN group, 50% in the newly suspected LPLN group, 9.1% in the responded LPLN group, and 19.6% in the persistently suspected LPLN group. By 2 years, recurrence rates increased to 9.1% in the non-suspected LPLN group, 100% in the newly suspected LPLN group, 27.3% in the responded LPLN group, and 41% in the persistently suspected LPLN group. Notably, in the newly suspected LPLN group, both cases experienced recurrence within 2 years, involving both locoregional and distant sites. Overall, recurrence rates were higher in patients with suspected LPLNs, with persistently suspected LPLNs showing a higher recurrence rate compared to responded LPLNs.

Survival analysis revealed that the recurrence rate in the newly suspected LPLN group was significantly worse, with a hazard ratio (HR) of 8.95 (95% CI: 2.02–39.63, $p = 0.004$). In contrast, the responded LPLN group showed an HR of 1.11 (95% CI: 0.33–3.74, $p = 0.865$), and the persistently suspected LPLN group had an HR of 1.23 (95% CI: 0.56–2.67, $p = 0.607$), indicating no significant differences in recurrence rates when compared to the non-suspected LPLN group (Figure 2).

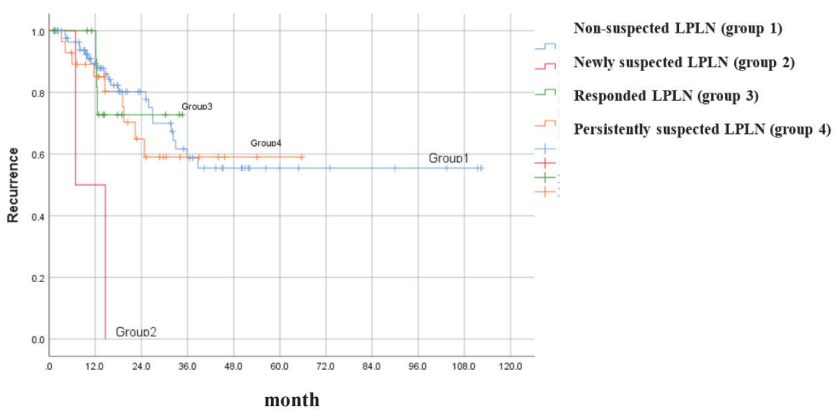

Figure 2 Survival analysis for recurrence

Univariate analysis evaluating LPLN factors affecting recurrence revealed that pre-treatment factors such as size, location, and side did not significantly influence recurrence risk. However, post-treatment analysis indicated that the location of LPLNs in the obturator region and unilateral involvement were significantly associated with an increased risk of locoregional recurrence (Table 3).

Table 3 Univariate analysis evaluating LPLN factors affecting recurrence

LPLN factors	Number of patients	Overall recurrence	N (%)	Locoregional recurrence	Distant recurrence
Pre-treatment					
Size and Morphology					
Non-suspected	88	1	24 (27.3)	1	1
Suspected	43	0.91 (0.45-1.82), 0.785	12 (27.9)	1.31 (0.47-3.61), 0.605	1.08 (0.50-2.31), 0.845
Location					
None	88	1	24 (27.3)	1	1
Internal iliac	13	1.16 (0.40-3.34), 0.788	4 (30.8)	1.37 (0.30-6.29), 0.683	1.02 (0.30-3.45), 0.972
Obturator	27	1.08 (0.47-2.52), 0.850	7 (25.9)	1.48 (0.46-4.75), 0.508	1.08 (0.43-2.71), 0.862
Both	3	1.02 (0.14-7.52), 0.987	1 (33.3)	NA	1.25 (0.17-9.30), 0.830
Side					
None	88	1	24 (27.3)	1	1
Unilateral	38	1.13 (0.55-2.31), 0.742	10 (26.3)	1.46 (0.53-4.03), 0.465	1.09 (0.49-2.39), 0.838
Bilateral	5	0.87 (0.12-6.49), 0.896	2 (40)	NA	1.02 (0.14-7.62), 0.985
Post-treatment					
Size and Morphology					
Non-suspected	101	1	25 (24.7)	1	1
Suspected	30	1.44 (0.71-2.92), 0.318	11 (36.7)	2.47 (0.92-6.64), 0.073	1.38 (0.63-3.02), 0.418
Location					
None	101	1	25 (24.7)	1	1
Internal iliac	10	1.68 (0.58-4.87), 0.335	4 (40)	2.22 (0.48-10.32), 0.309	1.50 (0.44-5.05), 0.516
Obturator	18	1.54 (0.63-3.78), 0.344	6 (33.3)	3.35 (1.12-10.03), 0.031	1.52 (0.57-4.05), 0.405
Both	2	1.23 (0.17-9.11), 0.840	1 (50)	NA	1.51 (0.20-11.28), 0.688
Side					
None	101	1	25 (24.7)	1	1
Unilateral	28	1.52 (0.73-3.16), 0.266	11 (39.3)	2.87 (1.06-7.71), 0.037	1.43 (0.63-3.23), 0.389
Bilateral	2	0.95 (0.13-6.91), 0.947	0 (0)	NA	1.08 (0.15-8.08), 0.937

Hazard ratio HR (95% CI), *p*-value
NA - not applicable

Our study's univariate analysis identified age < 50 years, EMVI, pT stage (especially pT4), CRM involvement, and pathologic node positivity as factors associated with recurrence. However, multivariate analysis revealed that only pathologic nodal staging remained an independent predictor of recurrence (Appendix 1).

Discussion

Our study found a recurrence rate of approximately 27.5%, with locoregional recurrence at 12.2% and distant recurrence at 22.9%. This differs from the study by Beck et al., which reported an overall recurrence rate of 52.9%, locoregional recurrence of 17.9%, and distant recurrence

of 35.6%. Notably, in that study, only 45.8% of patients received both CRT and adjuvant therapy, with more than half undergoing surgery alone.[27] CRT plays a crucial role in reducing locoregional recurrence by downstaging the tumor and improving local control. In contrast, adjuvant chemotherapy helps decrease systemic recurrence by targeting micrometastases that may not be eradicated by local treatment alone. Notably, distant recurrence was higher than locoregional recurrence, which may be attributed to the fact that 20.6% of patients in this study did not receive adjuvant chemotherapy (Table 1), potentially impacting the systemic recurrence rate.

When examining locoregional recurrence rates in each group, our study found rates of 9.4% in the non-suspected LPLN group, 6.7% in the responded LPLN group, and 17.8% in the persistently suspected LPLN group. In comparison, the newly suspected group had a 100% recurrence rate (Table 2). These findings are comparable to those reported by Ogura et al., who reported locoregional recurrence rates of approximately 10% in patients with no visible or non-suspected LPLNs and around 20% in the suspected LPLN group.[10] However, their study did not specifically address LPLN progression after CRT. In contrast, our study highlights that patients who developed newly suspected LPLNs after preoperative CRT had a significantly higher recurrence risk compared to both the non-suspected and clinically suspected LPLN groups, regardless of their response to CRT. This underscores the critical role of post-CRT imaging in identifying high-risk patients who may benefit from more aggressive treatment strategies. Additionally, this suggests that radiation may help control the lateral pelvic compartment, given the technology now available to cover the lateral pelvis,[28] while the disease in the newly suspected LPLN group appears to be more aggressive and less responsive to CRT. Additionally, a lack of precise tools to assess LPLN metastasis prior to treatment may contribute to variability in the definition of reactive versus pathologic LNs,[29] as different studies use varying cutoff sizes. Even within radiology-specific studies like the MERCURRY study,[30] there is still no clear consensus. The high recurrence rates in the newly suspected LPLN group may be due to some patients having LPLN that were either undetectable or smaller than the cutoff size before CRT, leading to false negatives. Following CRT, these LPLNs may progress, indicating that lateral pelvic disease persists despite treatment. For instance, two patients had a progression of disease after CRT, with one presenting a 4 mm obturator LPLN without malignant features and the other with an LPLN that increased from undetectable to 10 mm with malignant features post-CRT, though neither developed lateral local recurrence, with all recurrences being central. This differs from previous studies, which did not address the relationship between newly suspected LPLN and recurrence or poor prognosis, and provides new information that may warrant more careful consideration for this patient group.

In this study, locoregional recurrence occurred in 16 patients (12.2%), with only one case (6%) of lateral local recurrence, which was in the persistently suspected LPLN group. The patient had an extremely large LPLN of 18 mm pre-treatment, which decreased to 13 mm post-radiation. When compared with Kim et al.'s 2008 study, which found a 7.9% locoregional recurrence rate after CRT followed by TME, with lateral local recurrence making up 82.7% of cases, the difference might be explained by current radiation techniques covering the lateral pelvis. Furthermore, in the study by Kim et al., 87.5% of patients with lateral local recurrence had LPLNs larger than 10 mm, whereas only 4.3% had LPLNs smaller than 5 mm.[9] Our study indicates that unilateral involvement and obturator location are significant factors associated with higher rates of locoregional recurrence, a finding supported by the research of Kim et al. Their study demonstrated that irradiated patients with LPN metastasis had outcomes comparable to those with mesorectal node metastasis. Specifically, metastasis in internal iliac LPNs was similar to perirectal node metastasis, while metastasis in external LPLNs, including the obturator group, was analogous to intermediate LN metastasis.[31]

The limitations of our study include its retrospective design, small sample size, short follow-up period, and the fact that some patient data was collected during the COVID-19 pandemic, which may have influenced patient follow-up and the appropriateness of some treatments.

Conclusion

In conclusion, this study demonstrates that the recurrence rate of rectal cancer remains substantial, strongly influenced by the LPLN response to CRT. While locoregional recurrence was relatively low in non-progression groups, newly suspected LPLN cases showed a dramati-

cally higher risk. LPLN progression after CRT is a key predictor of recurrence, emphasizing the critical role of post-treatment imaging in risk assessment and treatment planning.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Appendix 1 Univariate and multivariate analysis for recurrence

Variable	Number of patients	Univariate HR (95% CI)	*p*-value	Multivariate HR (95% CI)	*p*-value
Age (y)					
≥ 50	108	Ref.			
< 50	23	2.24 (1.07, 4.65)	0.031	1.34 (0.55, 3.28)	0.522
Gender					
Female	51	Ref.			
Male	80	0.87 (0.44, 1.70)	0.676		
CEA					
≤ 5	68	Ref.			
> 5	63	1.12 (0.58, 2.16)	0.731		
ASA					
1,2	70	Ref.			
3,4	61	0.90 (0.46, 1.75)	0.759		
Tumor Location					
Mid, < 5 cm	70	Ref.			
Low, ≤ 5 cm	61	1.36 (0.71, 2.62)	0.354		
cT stage					
cT3	96	Ref.			
cT4	34	2.02 (0.99, 4.14)	0.053	0.98 (0.30, 3.21)	0.975
EMVI					
No	104	Ref.			
Yes	27	2.69 (1.34, 5.40)	0.006	1.39 (0.53, 3.61)	0.502
cN stage					
cN0	13	Ref.			
cN1	90	1.66 (0.39, 7.06)	0.492		
cN2	28	3.52 (0.78, 15.94)	0.103		
pT stage					
pT0	16	Ref.			
pT1,2	23	1.67 (0.17, 16.10)	0.655	1.46 (0.14, 14.62)	0.749
pT3	70	4.56 (0.61, 33.98)	0.138	2.45 (0.30, 19.72)	0.399
pT4	22	8.97 (1.16, 69.50)	0.036	3.00 (0.30, 30.46)	0.353
CRM					
Negative	125	Ref.			
Positive	6	3.04 (1.07, 8.62)	0.037	1.77 (0.45, 6.90)	0.411
pN stage					
pN0	83	Ref.			
pN1	29	0.22 (0.09, 0.51)	< 0.01	3.37 (1.43, 7.94)	0.006
pN2	19	0.99 (0.46, 2.16)	0.995	3.33 (1.27, 8.77)	0.015
Adjuvant Chemotherapy					
No	27	Ref.			
Yes	104	1.51 (0.46, 4.98)	0.497		

Ref. – Reference

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Original Article

Ultrasonic Assessment of Diaphragm Function in the Ventilator Liberation of Perioperative Patients

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Abstract

Objective: Diaphragm ultrasonography can predict weaning failure; however, only a small number of studies include the majority of surgery patients. This study seeks to investigate the feasibility of diaphragm ultrasonography-guided ventilator separation in intubated surgical patients.

Patients and Methods: This prospective observational study was conducted in postoperative mechanical ventilated patients at Surgical ICU, Maharaj Nakorn Chiang Mai Hospital, from September 2020 to September 2022. Diaphragm thickness (TDi) and diaphragm excursion (DE) were measured with ultrasonography during spontaneous breathing trials. We analyzed the correlation of diaphragm function to weaning success or failure. A weaning failure was defined as death or reintubation within 7 days after extubation (whether post-extubation noninvasive ventilation was used or not).

Results: 105 mechanically ventilated patients were prospectively recruited in the weaning failure group, 15 patients, and 90 patients in the weaning success group. The overall weaning failure rate was 14.29%. Patients who had undergone thoracic surgery significantly failed weaning more than those who had not (33% vs 11%, *p*-value 0.023). TDi at inspiration and expiration, both left and right diaphragm, DTF, and left DE did not differ significantly between patients who succeeded or failed ventilator weaning. Only right DE significantly differed between groups which were 6.7 [6.4-8.4] mm and 9.6 [7.4-14] mm (*p*-value 0.016) in the weaning failure group and success group, respectively. According to the ROC curve, a cutoff value of right diaphragm excursion > 7.3 mm was associated with a successful weaning with a sensitivity of 76.92%, a specificity of 69.23%, a positive predictive value of 93.75%, and a negative predictive value of 33.34%.

Conclusions: This study shows that in our cohort of postoperative patients, the assessment of right diaphragm excursion by ultrasound potentially predicts weaning success with a cutoff value > 7.3 mm (sensitivity of 76.92%, a specificity of 69.23%).

Keywords: Diaphragm, Ultrasound, Weaning, Perioperative, Surgery

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Introduction

Some surgical patients commonly require post-operative ventilation support and intensive care. According to a THAI-SICU study, the incidence of respiratory failures in surgical ICUs was 2.1-3.7%.[1] Patients who require mechanical ventilation spend roughly 15837.4 baht more than patients who do not.[2] Delayed ventilator weaning resulted in prolonged mechanical ventilation time, which in turn prolonged ICU stay and pulmonary complications like ventilator-associated infections[3-5] and ventilator-induced lung injury.[6-8] Early weaning can potentially result in extubation failure and cardiovascular complications, both of which can be fatal.[9] Therefore, choosing the right patients for weaning and extubation is necessary. In addition to muscle weakness, malnutrition, neurologic dysfunction, and cardiac dysfunction, diaphragm dysfunction is one of the causes of weaning failure.[10]

Critical patients frequently experience diaphragm dysfunction,[11] which increases mortality and length of mechanical ventilation.[12] Diaphragm dysfunction can be brought on by a variety of conditions, including sepsis, ventilator-induced diaphragmatic dysfunction (VIDD), and ICU-acquired diaphragm weakness.[13] Diaphragm dysfunction can also result from upper abdominal[14-16] and cardiac surgery.[17]

Many parameters have been developed over the years to determine whether or not patients will succeed in weaning themselves off of their ventilators and being extubated, such as spontaneous minute ventilation, maximum inspiratory pressure (PImax), rapid shallow breathing index (RSBI), and tracheal airway occlusion pressure of 0.1 seconds (P0.1).18 RSBI is one of the most reliable and feasible parameters for predicting whether a patient will successfully separate from a ventilator.[19,20]

In the past, evaluation of diaphragm function was only possible using invasive instruments or exposure to radiation. The results also required an expert to interpret them.[21] It was, therefore, impractical to assess diaphragm function in a patient receiving critical care. Nowadays, however, ultrasonography quality has increased and is practical in many scenarios, including bedside assessment of critically sick patients and the evaluation of diaphragm function. Diaphragmatic excursion, diaphragmatic thickness, and diaphragmatic contraction speed can all be determined using ultrasonographic diaphragm examination.[22] Ultrasonic diaphragm assessment is effective at predicting ventilator separation success,[23-25] with sensitivity and specificity of 0.85 (95% CI 0.77-0.99) and 0.74 (95% CI 0.66-0.8),[24] respectively, according to several systematic reviews and meta-analyses. Nevertheless, few studies include most of the patients who have undergone surgery.

This study aims to determine whether intubated surgical patients can successfully separate from their ventilators by using diaphragm ultrasonography.

Patients and Methods

This is a single-center, prospective observational study conducted on SICU patients at Maharaj Nakorn Chiang Mai Hospital from September 2020 to September 2022, in which diaphragm function was measured using ultrasound during a spontaneous breathing trial. The study was approved by the Ethics Committee of the Faculty of Medicine, Chiangmai University (study code: SUR-2563-07301). The inclusion criteria for this study are as follows: patients must be 20 years of age or older, including those who have undergone urgent, emergent, or elective surgeries. The patients should also be intubated or have a tracheostomy and be under invasive mechanical ventilation. Additionally, the patients must be ready to undergo a spontaneous breathing trial. There should be no contraindications to performing ultrasonic assessments in the relevant anatomical area, and the patient must have provided written informed consent. The exclusion criteria for this study include pregnancy, the presence of neuromuscular disease, and diaphragm paralysis. Additionally, patients who cannot be properly visualized for diaphragm assessment through ultrasound will be excluded. The sample size, calculated with an estimated 15% dropout rate, was 106 patients (Supplement 1).

Supplement 1 Sample size calculation

Formula	Previous study	Sample size
Estimation of sample size from AUC $n = \frac{Z_{\alpha}^{2} V(\widehat{AUC})}{d^{2}}$ $V(\widehat{AUC}) = (0.0099 x e^{-a^{2}/2}) x (6a^{2} + 16)$ $a = \varphi^{-1}(AUC) x 1.414$ φ^{-1} $= inverse\ of\ standard\ normal\ distribution$ $= 0.9284$	Weaning success predictability (AUC) = 0.90 Precision of estimation (d) = 0.05	Total estimated N = 91.8 ***= 92 patients***

The estimated dropout rate was 15%, and the total sample size was 106 patients.

Study protocol

When the inclusion criteria were reached, a spontaneous breathing trial was attempted. All patients were evaluated in a semi-recumbent position (30-45 degrees) within 2 hours of the spontaneous breathing trial (SBT) period. Then, each diaphragm was evaluated by B-mode and M-mode ultrasound using Esaote® MyLab™ Gamma Ultrasound. Weaning index parameters were recorded. All patients who did not fail the SBT would be extubated. Criteria for failure to the SBT were the following: change in mental status, onset of discomfort, diaphoresis, respiratory rate > 35 breaths/min, hemodynamic instability (heart rate > 140, systolic blood pressure > 180 or < 90 mmHg), or signs of increased work of breathing. Weaning failure (or separation failure) was defined as death or reintubation within 7 days after extubation (whether post-extubation noninvasive ventilation was used or not).[26]

The intensive care unit staff or radiologists trained the doctors who performed diaphragm ultrasounds until diaphragm ultrasound proficiency was certified.

Diaphragmatic ultrasound[27-29]

1. Diaphragm excursion

The liver or spleen is used as an acoustic window in the subcostal area, between the mid-clavicular and anterior axillary lines. A cardiac or abdominal probe (1–5 MHz) can be used. The diaphragm is identified as a hyperechoic line (produced by the pleura tightly adherent to the muscle) that approaches the probe during inspiration. The inspiratory excursion can be easily measured in M-mode (Diaphragm excursion; DE).

2. Diaphragm thickness

At the zone of apposition, between the 8th and 10th intercostal space in the mid-axillary or antero-axillary line, 0.5–2 cm below the costophrenic sinus. A linear high-frequency probe (6-13 MHz) is mandatory to obtain adequate diaphragmatic thickness images. At a depth of 1.5–3 cm, two parallel echogenic layers can be easily identified: the nearest line is the parietal pleura, and the deeper one is the peritoneum. The diaphragm is the less echogenic structure in between these two lines. This approach is utilized to assess the thickness of the diaphragm and thickening with inspiration (Diaphragmatic thickness at end inspiration; TDiins, Diaphragmatic thickness at end-expiration; TDiexp), usually in M-mode. Diaphragm thickness fraction (DTF) can be calculated from $\left(\frac{TDi_{ins} - TDi_{exp}}{TDi_{exp}}\right) \times 100$

Data analysis

Data are presented as mean (SD) or median [interquartile range] when appropriate. The χ^2 test, with Fisher correction when appropriate, was used for comparisons among categorical variables. Continuous variables were compared with the student *t*-test, Mann-Whiney U test, and Wilcoxon sign rank test. Receiver operating characteristic (ROC) curve analysis was performed to assess the diaphragm ultrasound ability to discriminate between patients who succeeded in weaning and those who failed. A two-tailed *p*-value of less than 0.05 was taken to indicate statistical significance.

Results

A total of 152 patients were enrolled in this study. Of these, 47 patients were excluded due to incomplete data records, inability to perform diaphragmatic ultrasound, non-intubation status, or not undergoing surgery. This left 105 participants for the final analysis, comprising 15 patients in the weaning failure group and 90 patients in the weaning success group (Figure 1). The weaning failure rate was 14.29%, consistent with the findings from the WIND study.[26] The baseline characteristics of the two groups were not statistically significantly different, except for a higher prevalence of immunocompromised status and thoracic operations in the weaning failure group (Table 1).

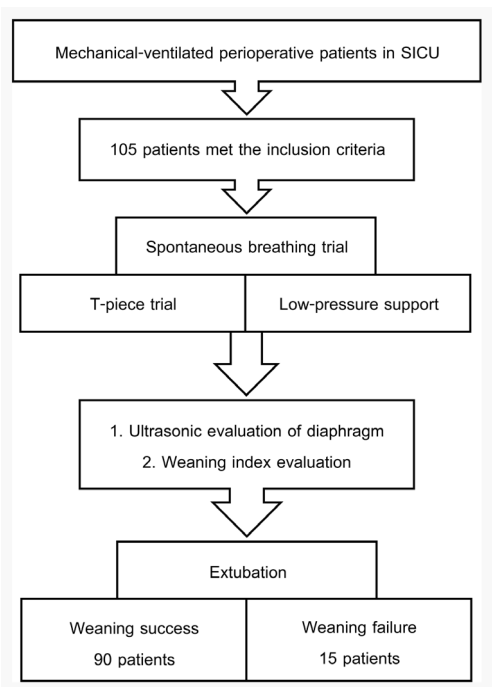

Figure 1 Flow chart of study design and included participants

Table 1 Characteristic data of the extubated patients

Characteristic	All n = 105 (%)	Weaning failure 15 (14.29%)	Weaning success 90 (85.71%)	*P*-value
Age (year)	65 [54-74]	70 [64-75]	64 [51-74]	0.113
BMI (kg/m²)	21.93 [19.53-24.44]	23.83 [21.48-26.67]	21.76 [19.38-24.22]	0.057
Male	59 (56.73)	9 (64.29)	50 (55.56)	0.540
ASA				0.928
Class 1	1 (0.95)	0 (0.00)	1 (1.11)	
Class 2	39 (37.14)	5 (33.33)	34 (37.78)	
Class 3	42 (40.00)	7 (46.67)	35 (38.89)	
Class 4	23 (21.90)	3 (20.00)	20 (22.22)	
Class 5	0 (0.00)	0 (0.00)	0 (0.00)	
Comorbidity				
Hypertension	52 (50.00)	11 (73.33)	41 (46.07)	0.051
Diabetes	27 (25.71)	5 (33.33)	22 (24.44)	0.466
COPD	6 (5.71)	0 (0.00)	6 (6.67)	0.303
CVS disease	23 (21.90)	5 (33.33)	18 (20.00)	0.248
Cancer	27 (25.71)	2 (13.33)	25 (27.78)	0.236
Cirrhosis	4 (3.81)	0 (0.00)	4 (4.44)	0.405
CKD	14 (13.33)	0 (0.00)	14 (15.56)	0.101
Immunocompromise	5 (4.76)	3 (20.00)	2 (2.22)	0.003
Surgery				
Abdominal	54 (51.43)	5 (33.33)	49 (54.44)	0.130
Thoracic	15 (14.29)	5 (33.33)	10 (11.11)	0.023
Vascular	23 (21.90)	4 (26.67)	19 (21.11)	0.630
Urologic	11 (10.48)	0 (0.00)	11 (12.22)	0.152
Head, neck, and soft tissue	5 (4.76)	0 (0.00)	5 (5.56)	0.350
Duration of MV	2 (1-4)	3.5 (2-8.5)	2 (1-4)	0.078
Reason for MV				0.488
Hypoxemic	17 (16.19)	4 (26.67)	13 (14.44)	
Hypercapnic	0 (0.00)	0 (0.00)	0 (0.00)	
Peri-operative	81 (77.14)	10 (66.67)	71 (78.89)	
Shock	7 (6.67)	1 (6.67)	6 (6.67)	

Diaphragm thickness during inspiration and expiration did not differ significantly between patients who succeeded or failed ventilator weaning for both the left and right diaphragms. In the weaning failure group, the mean thickness of the right and left diaphragm during inspiration and expiration was 2.4 mm, 1.5 mm, 2.5mm, and 1.5 mm, respectively. In the weaning success group, the mean thickness of the right and left diaphragm during inspiration and expiration was 2.3 mm, 1.7 mm, 2.3 mm, and 1.63 mm, respectively. Therefore, there was no significant difference in DTF between patients who failed and those who succeeded in weaning. Right, Diaphragm excursion was 6.7 [6.4-8.4] mm in the weaning failure group and 9.6 [7.4-14] mm in the weaning success group, with a statistically significant difference between the two groups. However, the left diaphragm excursion did not differ significantly. None of the ventilator weaning indices differed between patients who failed and those who succeeded in weaning (Table 2). Figure 2 shows a DTF(a) and DE(b) boxplot.

Table 2 Diaphragm ultrasound and weaning index in weaning failure and success groups

Parameters	All 105	Weaning failure 15 (14.29%)	Weaning success 90 (85.71%)	*P*-value
TDi_{ins} (mm)				
Right	2.3 [1.73-3]	2.4 [1.4-2.8]	2.3 [1.8-3]	0.675
Left	2.3 [1.8-2.83]	2.5 [1.9-2.7]	2.3 [1.8-2.83]	0.756
TDi_{exp} (mm)				
Right	1.7 [1.2-2.4]	1.5 [0.85-2.2]	1.7 [1.26-2.4]	0.525
Left	1.62 [1.3-2.2]	1.5 [0.9-2.0]	1.63 [1.3-2.2]	0.412
DTF (%)				
Right	35 [23.75-54]	56 [28-61]	34 [23-50]	0.117
Left	37.25 [21.5-49.35]	56 [31-63]	36 [21-47]	0.068
DE (mm)				
Right	9.33 [6.8-13]	6.7 [6.4-8.4]	9.6 [7.4-14]	**0.016**
Left	9.1 [6.7-12.5]	7.8 [5.4-13]	9.15 [6.75-12.25]	0.792
Spontaneous MV	7.5 [6.5-9.5]	8.52 [6.37-9.9]	7.46 [6.5-9.4]	0.551
Spontaneous RR	18 [14-20]	18 [16-22]	17.5 [14-20]	0.120
Spontaneous VT	420 [354-523]	398 [300-502]	420 [357-524]	0.404
TV by weight	7.38 [6.36-9.67]	6.94 [5.59-7.71]	7.65 [6.4-9.94]	0.116
P 0.1	-2 [-3.9, -1.2]	-2 [-5.6, -1.1]	-2 [-3.55, -1.2]	0.824
NIF	-20 [-28, -15]	-20 [-28, -11]	-20.5 [-27.5, -15]	0.842
Cdyn	57.14 [48-71.4]	56.86 [42.8-75]	57.57 [48.3-66.79]	0.994
RSBI	41 [27-51]	40 [22-53]	41 [27.5-50.5]	0.930
Duration of SCIU stay	4 [2-10]	19 [12-23]	3 [2-7]	< 0.001
Mortality	14 [13.33]	7 [46.67]	7 [7.78]	< 0.001

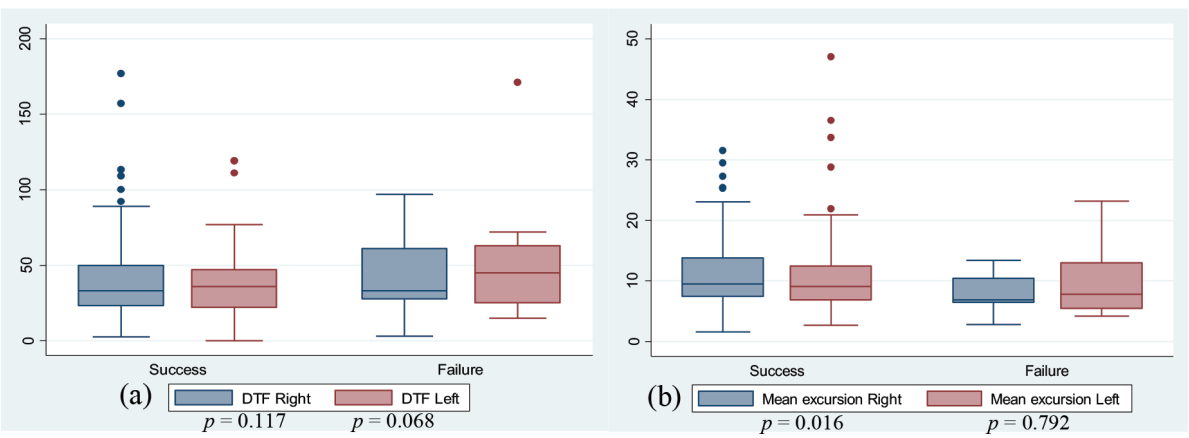

Figure 2 Boxplot of DTF(a) and DE(b): the central line represents the median value, the box boundaries represent the 25th and 75th percentiles, the lines represent the lowest datum within 1.5 inter-quartile range (IQR) of the lower quartile and the highest datum within 1.5 IQR of the upper quartile, and the circles represent outlier values.

According to the ROC curve, a cutoff value of right diaphragm excursion > 7.3 mm was associated with successful weaning, with a sensitivity of 76.92%, a specificity of 69.23%, a positive predictive value of 93.75%, and a negative predictive value of 33.34% (Figure 3).

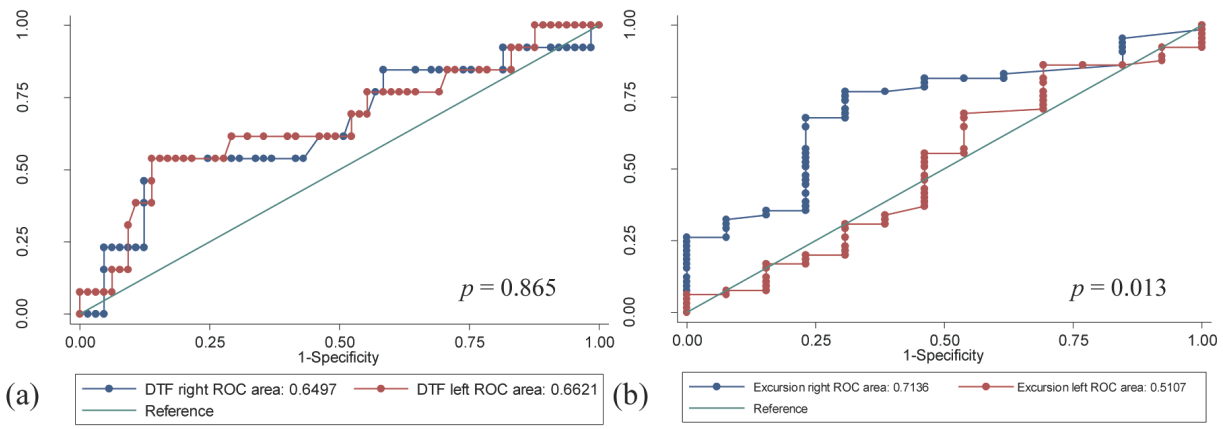

Figure 3 ROC curve for DTF (a) and DE (b): DTF right and left shows ROC area (95% CI), 0.6497 (0.47-0.83) and 0.6621 (0.48-0.84), respectively (*p*-value 0.865). DE right and left shows ROC area (95% CI), 0.7136 (0.57-0.86) and 0.5107 (0.32-0.7), respectively (*p*-value 0.013)

The length of ICU stays, and mortality rate was higher in the patients who failed to wean than in those who succeeded: 19 [12-23] vs. 3 [2-7] days and 46.7% vs. 7.78%, respectively (Table 2).

Discussion

This study shows that right diaphragm excursion > 7.3 mm is potentially useful in predicting weaning success in postoperative patients with a sensitivity of 76.92% and a specificity of 69.23%. However, there was no difference in diaphragm thickness between patients who failed or succeeded in weaning. Other ventilator weaning indexes were also not significantly different between the two groups.

Ultrasound is a technology that is increasingly used in intensive care units. It is used for central line placement, fluid responsiveness, and, recently, diaphragm function.[27] Numerous studies today demonstrate that diaphragm ultrasound can be used to evaluate diaphragm function. Valette's study in medical ICU patients showed that the diaphragm dysfunction criteria were excursion < 10 mm or paradoxical movement during inspiration.[30] Another study in the medical ICU by Kim used right and left diaphragm excursion > 14 mm and > 12 mm to predict weaning success, with a sensitivity of 60%, a specificity of 76%, and an ROC area of 0.68.[22]

To our knowledge, few studies include postoperative patients. For example, E.R. Ali and colleagues' study, which included only 6 postoperative patients from a total of 60 patients, showed that mean diaphragm thickness > 2 mm, DTF > 30%, and DE > 15 mm can predict successful weaning.[31] M. Zambon's systemic review of diaphragm ultrasound concluded that diaphragm dysfunction was DE < 10-14 mm and DTF < 30-36%.[25] Nevertheless, our study, which includes only postoperative patients, shows that only the right DE may potentially predict successful weaning. Surgery may cause diaphragm malfunction, which could account for why there is no significant difference between diaphragm thickness and DTF. Ford and colleagues' study showed reduced diaphragm activity in the postoperative period, with a shift from predominantly abdominal to rib cage breathing.[32] The same effect of the surgery on the diaphragm was also demonstrated in B. Dureuil's study.[14] The weaning index from this study does not significantly differ between patients who failed and those who succeeded in weaning, probably because we included only those who succeeded in SBT.

Our study has some limitations. The first is that many different physicians performed diaphragm ultrasound, which is operator dependent. Future studies designed to demonstrate intra- and inter-observer variability are required. The validity of the diaphragm ultrasound parameter from our study is limited to postoperative patients.

Conclusion

This study shows that in our cohort of postoperative patients, the assessment of right diaphragm excursion by ultrasound potentially predicts weaning success with a cutoff value > 7.3 mm (sensitivity of 76.92%, a specificity of 69.23%).

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Conflict of Interest

The authors disclose no conflict of interest.

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Case Report

Precision Mapping: Intraoperative Indocyanine-Green Video Angiography in Thoracic Spinal Dural Arteriovenous Fistula, The Surgical Management: A Case Report

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Abstract

Background: The sudden or gradual onset of bilateral lower limb weakness, coupled with sensory deficits and alteration in reflex activity, should give rise to significant concern for potential emergent spinal conditions. The common spinal pathologies that we usually encounter are spinal cord compression, trauma, cauda equina syndrome, and Guillain-Barré syndrome. Conversely, there is a rare condition known as Foix-Alajouanine syndrome, which manifests with a wide spectrum of neurological symptoms originating from spinal vascular malformations. The formation of spinal dural arteriovenous fistula (dAVF) represents a prominent manifestation of Foix-Alajouanine syndrome.

Case Presentation: We report an uncommon case of thoracic spinal dural arteriovenous fistula (dAVF) managed through microsurgery with intraoperative Indocyanine-Green (ICG) video angiography assisted in a 37-year-old gentleman. This is a complex case, as the usual endovascular approach was not feasible due to the torturous configuration of the arterial feeder vessels. Our patient showed no neurological improvement during the 1st and 3rd-month follow-up evaluations, presumably owing to the delayed onset of the condition. Prolonged monitoring may unveil amelioration in our patient's symptoms.

Conclusion: Foix-Alajouanine syndrome, albeit uncommon, merits attention in cases of progressive myelopathy. Microsurgical intervention for spinal dural arteriovenous fistula (dAVF), complemented by intraoperative ICG video angiography, is an efficacious treatment strategy. Timely intervention is crucial for favorable outcomes.

Keywords: Spinal dural arteriovenous fistula (dAVF), Foix-Alajouanine syndrome, Microsurgery, Spinal vascular malformations

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Introduction

Acute or insidious development of bilateral lower limb weakness, accompanied by sensory loss, hypo- or hyperreflexia, and bladder dysfunction, should prompt a high level of suspicion for emergent spinal pathology. Examples, to name a few, include spinal cord compression or trauma, cauda equina syndrome, and Guillain-Barré syndrome. Additionally, there exists a rare condition called Foix-Alajouanine syndrome, characterized by a diverse array of neurological manifestations stemming from spinal vascular malformations. This syndrome is characterized by spinal vascular malformations, which can lead to venous congestion and ischemic myelopathy.[1] It predominantly affects the thoracic and/or lumbosacral regions, with spinal dural arteriovenous fistula (dAVF) representing a notable manifestation.[2] Here, we present a case of thoracic spinal dAVF managed through microsurgery with intraoperative Indocyanine-Green (ICG) video angiography assistance. The clinical presentation and treatment strategy are discussed in order to enhance disease awareness and facilitate early diagnosis.

Case Presentation

A 37-year-old gentleman with no significant past medical history presented with progressively worsening bilateral lower limb pain and weakness, persisting for three months. He had sought medical attention in emergency care multiple times over nine months. A physical examination of the patient revealed that he had no signs of external trauma along the spinal column. However, there was diminished strength in lower limbs, with Medical Research Council (MRC) scores of 2 for hip and knee movements and 1 for ankle movements. He lacked the ability to stand or walk unaided without risking safety and exhibited reduced sensory perception extending bilaterally from the L2 dermatome downwards, along with perineal anesthesia and absent reflexes. The rectal tone was also absent, with complaints of overflow incontinence. White cell counts, hemoglobin, platelet count, and renal profile were within normal limits. Anterior-posterior and lateral lumbosacral radiographs showed no abnormalities. Immediate magnetic resonance imaging (MRI) of the entire spine revealed central hyperintensity from the level T5 till the conus with dilated perimedullary veins on T2-weighted sagittal sequences (Figure 1A), indicative of spinal dAVF.[3] A magnetic resonance imaging (MRI) is a valuable tool for the initial assessment of spinal cord pathologies because it can precisely outline any abnormalities. Following that, the goal standard procedure, which is a spinal digital subtraction angiography (DSA), was done. The spinal digital subtraction angiography (DSA) revealed a Type IB thoracic dAVF supplied by left T5 and T6 radiculomedullary arteries and tortuous draining veins (Figure 1B) with long-segment tortuous dilated veins in the thoracic spinal column (Figure 1C). Endovascular treatment, with an up to 89.5% success rate and low morbidity, has emerged as the primary treatment for dAVF.[2] However, due to the narrow and tortuous vessel course (Figure 1B), endovascular treatment was deemed unfeasible for this case. Following multidisciplinary consultation, microsurgical occlusion of the spinal dAVF was performed. Under general anesthesia, the patient was placed prone, and a midline linear incision was made, followed by subperiosteal dissection. Intraoperative fluoroscopy confirmed vertebral levels, and a T4-T6 laminectomy was performed. Dura was opened midline, revealing severely dilated tortuous vessels at the dorsum of the spinal cord (Figure 2A). ICG administration enabled visualization of the arterialized vein early in the arterial phase (Figure 2B), followed by the dilated draining veins in the venous phase (Figure 2C). A temporary clip was applied to the arterialized vein near the fistulous point adjacent to the left T6 exiting nerve root (Figure 2D). Post-clip application ICG run demonstrated the obliteration of the arterialized vein while maintaining draining vein flow, albeit less intense than before (Figure 2E). The arterialized vein was coagulated and sectioned, followed by watertight fascia duraplasty and lamina replacement using titanium plates and screws. Following surgery, he stayed hospitalized for 1 month to undergo rehabilitation and physiotherapy. During this period, he experienced an uncomplicated recovery. However, lower limb motor strength remained unchanged, and urinary catheter dependency persisted. Finally, a rehabilitation program for outpatient care was started as soon as he was discharged. The program consisted of both passive and active assisted range of motion exercises, muscle strengthening routines, neuromuscular electrical stimulation, and balance training. Postoperative MRI showed resolved cord edema and dilated perimedullary vessels (Figure 3A), while DSA revealed no residual dAVF (Figure 3B).

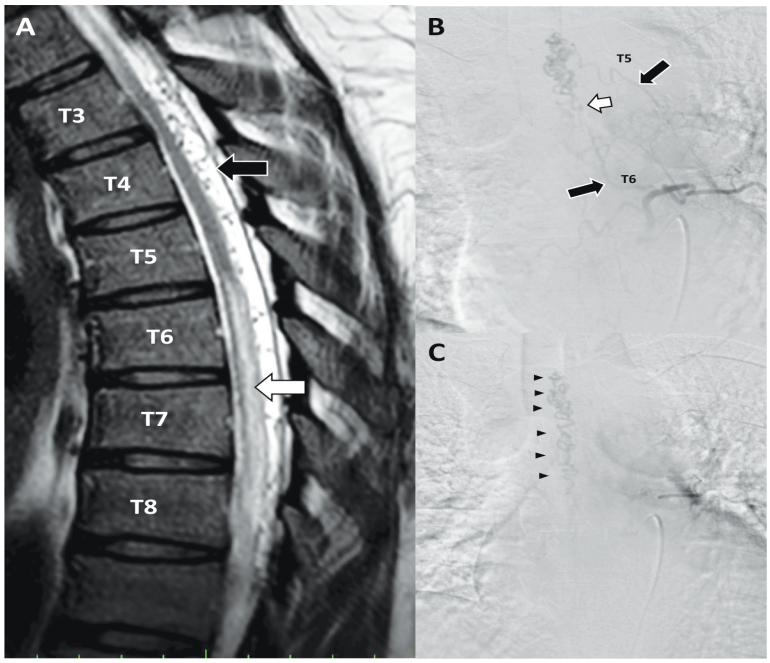

Figure 1 A: T2-weighted MRI of the sagittal thoracic spine revealed centromedullary hyperintensity extending from T5 to the conus (white arrow), accompanied by dilated perimedullary vessels (black arrow). These findings are characteristic of spinal dAVF.

B, C: DSA, following injection of the left T6 intercostal artery, demonstrated a thoracic spinal dAVF supplied by the left T5 and T6 radiculomedullary arteries (black arrows). The arterialized vein (white arrow) and dilated draining veins (multiple black arrowheads) were also observed.

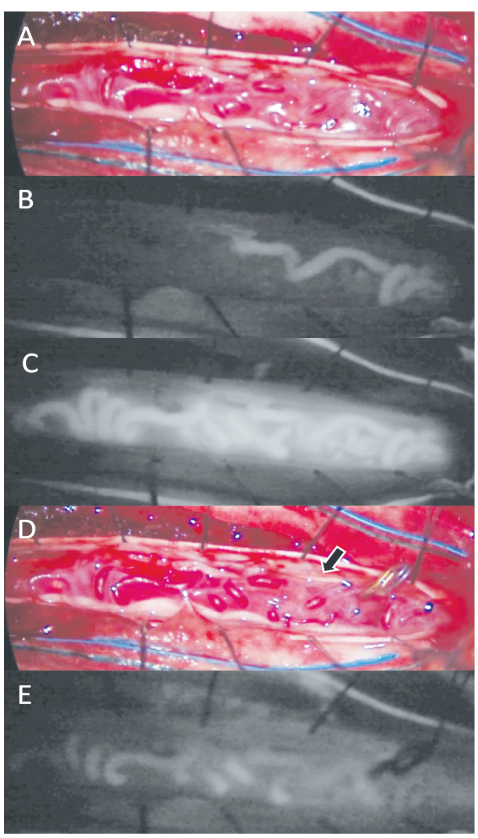

Figure 2 A - Upon durotomy, tortuous dilated vessels were observed at the dorsum of the spinal cord. Gross visualization revealed significant difficulty discerning the arterialized vein from the dilated draining veins.

B - Indocyanine-green was administered, highlighting the arterialized vein early in the arterial phase.

C - Indocyanine-green revealed the dilated draining veins during the venous phase.

D - A temporary clip was placed on the arterialized vein near the fistulous point, adjacent to the left T6 exiting nerve root (black arrow). Typically, the arterialized vein is supplied by the dura superficial to the nerve root.

E - Another indocyanine-green run demonstrated a disruption of blood flow to the arterialized vein while still maintaining flow to the draining veins, albeit with less intensity compared to before the fistula was obstructed.

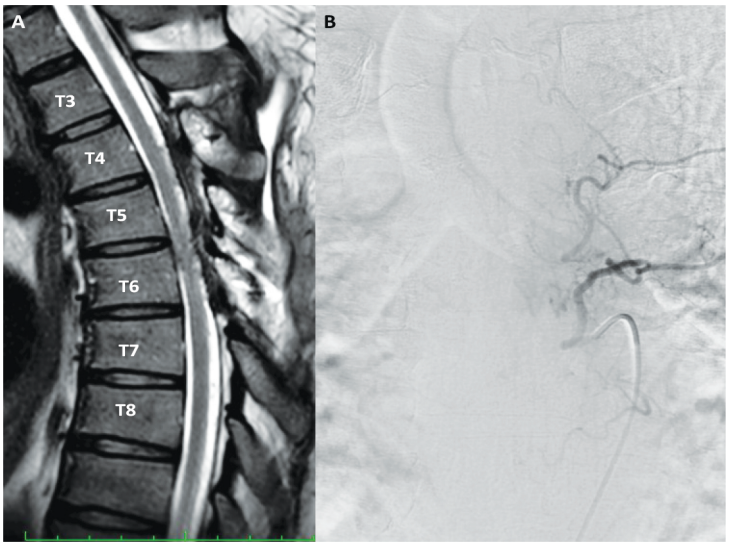

Figure 3 A: Post-operative MRI showed resolved cord oedema and dilated perimedullary vessels. B: DSA post-surgical occlusion revealed no residual dAVF.

Discussion

Spinal dural arteriovenous fistulas (dAVFs) are characterized by anomalous connections between arteries and veins without a distinct nidus. Despite their rarity, they are the most common type of spinal vascular malformation.[2] Foix-Alajouanine syndrome is not a standalone condition but rather a complication stemming from spinal dAVFs. Initially described by Foix and Alajouanine in 1926, this syndrome presents as necrotizing myelopathy, with further elucidation provided by Lhermitte in 1931. Aminoff and Logue proposed in 1974 that spinal arteriovenous fistulas (AVFs) lead to elevated intramedullary venous pressure, resulting in reduced arteriovenous pressure gradients and subsequent cord perfusion decline. Typi cally, the lower portion of the cord is predominantly affected, demonstrating signal alterations on MRI scans.[4] However, as evidenced by our case, misdiagnosis upon presentation is not uncommon, necessitating a high index of suspicion due to the exclusion of other urgent spinal pathologies during emergency department assessments. Patients with Foix-Alajouanine syndrome may present with progressive unilateral or bilateral weakness, sensory disturbances, and bladder, bowel, and sexual dysfunction, which can progress over several years before a diagnosis is established.[5] In this current case, the patient has reported experiencing bilateral lower limb weakness and pain that started nine months ago and has since shown a gradual deterioration, notably over the past three months. Radiological evaluation, including MRI and digital subtraction angiography (DSA), was crucial for distinguishing Foix-Alajouanine syndrome from other causes of progressive myelopathy and facilitated the formulation of an appropriate management strategy to impede disease advancement. MRI findings may initially appear normal but progress to show inflammation and hypointensity on T1 sequences and hyperintensity on T2 sequences, accompanied by dilated perimedullary vessels.[3,6] Phase-contrast MRI often reveals enlarged, tortuous vessels within the subarachnoid space. However, diagnosing spinal arteriovenous lesions can be challenging, with studies suggesting significant delays in accurate diagnosis.[7] The optimal treatment strategies for spinal dAVF encompass a spectrum of approaches, including endovascular therapy involving embolization, surgical ligation of the arteriovenous fistulas (AVFs), or a combination of both modalities in certain cases.[2] While surgery traditionally offers a potential cure for the lesion, endovascular treatment has gained momentum recently due to its high success rates (up to 89.5%), lower morbidity, and shorter hospital stays.[2,8] Following consultation with our neuro-interventional radiologist, microsurgical occlusion was determined to be the most suitable treatment option, given the narrow and tortuous nature of the arterial feeder, making endovascular treatment more challenging. Surgical intervention typically results in a higher rate of fistula obliteration compared to endovas-

cular techniques.[2] It is imperative to highlight that successful microsurgical occlusion of dAVF necessitates the occlusion of the arterialized vein rather than the arterial feeder, as failure to do so may lead to the recruitment of new feeding arteries and subsequent recurrence.[2] During the intraoperative phase, distinguishing between the arterialized and draining veins can pose challenges. Furthermore, there is a risk of catastrophic hemorrhage if the dilated draining veins are inadvertently occluded instead of the arterialized vein. Thus, intraoperative ICG video angiography serves as a valuable adjunct in identifying the arterialized vein, aiding in precise treatment delivery. Surgical treatment carries potential complications, including wound infection, cerebrospinal fluid (CSF) leaks, pseudomeningocele, hematoma, neurovascular injury, worsening myelopathy, and pressure sores.[8] Our patient experienced a post-operative pseudomeningocele, managed conservatively. The primary goal of treatment for spinal dAVFs is to prevent further neurological deterioration and promote functional recovery. A meta-analysis conducted by Steinmetz et al. demonstrated that surgical intervention resulted in improvement or stabilization of symptoms in up to 89% of patients with spinal dAVF, with 55% experiencing improvement, 11% experiencing worsening, and 34% remaining stable. However, only approximately one-third of patients reported improvement in urinary function following treatment.[9] Our patient did not exhibit neurological improvement at the 1st and 3rd-month follow-up assessments, likely due to the delayed presentation of the condition. A longer follow-up may reveal improvements in our patients' symptoms.

Conclusion

Foix-Alajouanine syndrome, although rare, warrants consideration in cases of progressive myelopathy. Microsurgical treatment of spinal dAVF, supplemented by intraoperative ICG video angiography, represents an effective management approach. Early intervention is pivotal for favorable outcomes, necessitating heightened clinical vigilance for prompt diagnosis and treatment initiation. The time elapsed between the onset of the neurological deficit and treatment can impact the patient's prognosis. The likelihood of regaining functional ambulation in patients with dAVF is closely linked to the timing of treatment. Delayed endovascular or surgical intervention results in poor prognosis, even in extended rehabilitation, as witnessed in this case.

Ethical statement

The authors are accountable for all aspects of the work and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient's parents to publish this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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30-Day Mortality of Palliative Shunt Surgery for Cyanotic Congenital Heart Disease at Maharat Nakhon Ratchasima Hospital

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Abstract

Background: Palliative shunt surgery in pediatric patients with cyanotic conditions is complex and challenging. Corrective surgery is necessary for patients with reduced pulmonary blood oxygenation to address these abnormalities. Following surgery, patients demonstrate an improved survival rate. However, this operation has a considerable mortality compared to the survival benefit.

Objective: To examine the 30-day postoperative mortality rate following palliative shunt surgery in patients with congenital heart disease for each type of procedure and to assess blood oxygen levels before and after surgery.

Patients and Methods: This study is a retrospective analysis collecting data on pediatric patients with cyanotic conditions who underwent palliative shunt surgery between January 1, 2020, and January 1, 2023. The patients were categorized into 4 procedural groups: Group 1, patients who underwent the modified Blalock-Taussig-Thomas shunt; Group 2, those who received the modified Waterston shunt; Group 3, patients with the central shunt; and Group 4, those who had the modified Pott's shunt, respectively.

Results: A total of 86 pediatric patients with cyanotic congenital heart conditions underwent palliative shunt surgery, primarily closed-heart procedures. Nearly three-quarters of the patients (65 cases, 75.5%) were between 1 day and 1 year old. The modified Blalock-Taussig-Thomas shunt was the most common procedure performed in 56 patients (65.1%). Postoperative blood oxygen levels showed a statistically significant increase compared to preoperative levels in both the modified Blalock-Taussig-Thomas shunt and modified Waterston shunt procedures. Among the 56 patients who underwent the modified Blalock-Taussig-Thomas shunt, the 30-day mortality rate was 3.6%. For the modified Waterston shunt performed on 24 patients, the 30-day mortality rate was 12.5%. The Central shunt procedure was performed on 5 patients, with a 30-day mortality rate of 4 cases (80%). Overall, the 30-day mortality rate across all 86 cyanotic congenital heart disease patients undergoing palliative shunt surgery was 10.5%.

Conclusion: Four palliative shunt procedures are closed-heart surgeries intended as interim measures before major corrective surgery to address intracardiac abnormalities. Following the corrective surgeries, postoperative blood oxygen levels were higher than preoperative levels.

Keywords: Palliative shunt surgery, Modified Blalock-Taussig-Thomas shunt, Modified Waterston shunt, Central shunt, Modified Pott's shunt

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Introduction

The incidence of congenital heart disease in the past was relatively low due to the limited availability of pediatric cardiologists and echocardiography equipment, which often resulted in undiagnosed cases and unexplained child fatalities. However, diagnostic advancements and expanding medical services into remote areas have significantly increased access to diagnosis and treatment for children with heart conditions, improving survival rates. Cyanotic conditions due to congenital heart disease are particularly prevalent and crucial to address. Cyanotic congenital heart disease can be categorized into two main groups. The first includes patients with increased pulmonary blood flow, where the mixing of oxygenated and deoxygenated blood occurs within the heart, resulting in inadequate oxygen levels in the systemic circulation. Conditions in this group include transposition of the great arteries, total anomalous pulmonary venous connection, tricuspid atresia, mitral valve atresia, and atrioventricular canal defect. The second group consists of patients with reduced pulmonary blood flow, often accompanied by a similar mixing of deoxygenated and oxygenated blood but with narrowed or obstructed pulmonary blood flow pathways (Right Ventricular Outflow Tract Obstruction). This results in decreased oxygen levels in the systemic circulation, with examples including tetralogy of Fallot, pulmonary atresia, and double outlet right ventricle with pulmonary stenosis.[1]

In pediatric cyanotic patients with reduced blood flow to the lungs, temporary surgery is currently performed to increase pulmonary blood flow by using a systemic-to-pulmonary shunt, thereby reducing cyanosis.[2] Once the critical phase is passed, an assessment is conducted to evaluate whether the pulmonary artery has grown enough to support a complete corrective surgery at a later stage, often involving a second shunt procedure. Systemic to pulmonary shunts are classified into 2 types: Peripheral shunts, which include the Blalock-Taussig-Thomas shunt that connects the subclavian or brachiocephalic artery to the right or left pulmonary artery. Central shunts (consisting of the Waterston shunt connecting the ascending aorta to the pulmonary artery), the Pott shunt (connecting the descending aorta to the pulmonary artery), and a central shunt that connects the ascending aorta to the main pulmonary artery. Previously, De Leval developed a method using synthetic grafts instead of natural vessels, which became widely used in Blalock-Taussig shunts.[3] Currently, synthetic PTFE grafts are employed, with the term "Modified" added to distinguish these from the original procedures that did not use synthetic grafts.

The surgery to create a systemic to pulmonary shunt in patients with congenital cyanotic heart disease is a therapeutic approach aimed at alleviating cyanosis in patients with limited pulmonary blood flow due to this condition. This procedure is particularly relevant for patients who are not yet candidates for complete corrective surgery, such as newborns, young children, or those whose conditions are unstable for definitive surgical intervention.[4] Acute shunt occlusion or blockage is a significant complication in pediatric patients undergoing systemic to pulmonary shunt surgery, potentially leading to mortality.[5-7] Various aspects will be considered to investigate the factors influencing patient mortality, which may benefit diagnosis and preventive planning. These include the size of the prosthetic vessel used in each procedure and the urgency of the surgery, whether elective or emergency. This information may assist in reducing subsequent complications.

In this study, we examined the outcomes of surgeries to create a prosthetic vessel to increase pulmonary blood flow in the modified Blalock-Taussig-Thomas shunt (mBTTS), modified Waterston shunt (mWTS), Central shunt (CentralS), and modified Pott's shunt (mPottS) procedures. Specifically, it focused on the 30-day mortality rate and the increase in blood oxygen levels before and after surgery in patients with congenital cyanotic heart disease.

Patients and Methods

Ethical committee approval was obtained from the Maharat Nakhon Ratchasima Hospital Institutional Review Board (022/2024). After informed consent, since this is a Retrospective descriptive study, data from eighty-six patients who underwent Operate Modified Blalock Taussig shunt, Modified Waterston shunt, Central shunt, and Modified Pott's shunt, respectively, were collected retrospectively from January 2020 to January 2023.

The primary outcome was 30-day mortality, and secondary outcomes were pre- and postoperative oxygen saturation, the correlation between the type of shunt and 30-day mortality, and the relationship between the elective emergency case and 30-day mortality.

Data collection

The authors collected demographic data, age, types of procedures, urgency of the operation, types of operations, graft size, cardiac care unit stays, hospital stays, and, lastly, 30-day mortality from the medical records.

Statistical analysis

The data were analyzed using SPSS version 29.0 and compared using an independent sample *t*-test. Categorical variables were reported as frequency and percentage of the total group and compared using the chi-square test. All p-values ≤ 0.05 were considered significant.

Surgical technique

The operation can be performed on either side through a lateral thoracotomy incision in the fourth intercostal space. The pulmonary artery is dissected for a modified Blalock-Taussig-Thomas shunt. An azygous vein was divided, and then a plain of dissection along the posterior superior vena cava (SVC) was dissected and mobilized anteriorly. The pericardial cavity was entered in this step. The ascending aorta and brachiocephalic artery were identified and mobilized. Heparin was given at 1 mg./Kg. A PTFE graft was selected for a mBTT shunt. Selection is based on the weight correlated with the graft size (shown in Table 1). A thin-wall PTFE graft was selected for shunting. The ascending aorta was clamped partially, aortotomy as long as the anastomotic line was decided, and then anastomosis was done with Prolene 6/0-7/0. The dissected pulmonary artery (PA) branch was clamped as proximally as possible, and arterotomy was created vertically. The distal end of the shunt was decided and trimmed for appropriate anastomosis on the pulmonary artery. Local heparin was rinsed into the shunt, and distal shunt anastomosis was done. Deairing by intermittent declamping of the pulmonary artery was done before the completion of the distal anastomosis. Subsequently, the pulmonary artery clamp was released, followed by the release of the aortic clamp. Finally, the lung was fully re-expanded.

Table 1 Correlation between body weight and PTFE graft size

Body weight (Kg.)	PTFE graft size (mm.)
< 2	3
2-3	3.5
3-5	4
5-15	5
>15	6

Following the anastomosis, hemodynamic parameters and oxygen saturation were monitored to compare values before and after the shunt. A chest drain was placed and connected to a water-sealed drainage system. The chest wall was then closed in layers. The patient was extubated when appropriate and transferred to the cardiac intensive care unit as part of the routine protocol.

Results

Baseline patient characteristics

In the study, a total of 86 patients underwent palliative shunt surgery for congenital cyanotic heart disease, with closed-heart procedures performed. Nearly three-quarters of the patients (65 cases, 75.5%) were aged from 1 day to 1 year, while 20 patients (24.1%) were aged between 1 year and 10 years (shown in Figure 1).

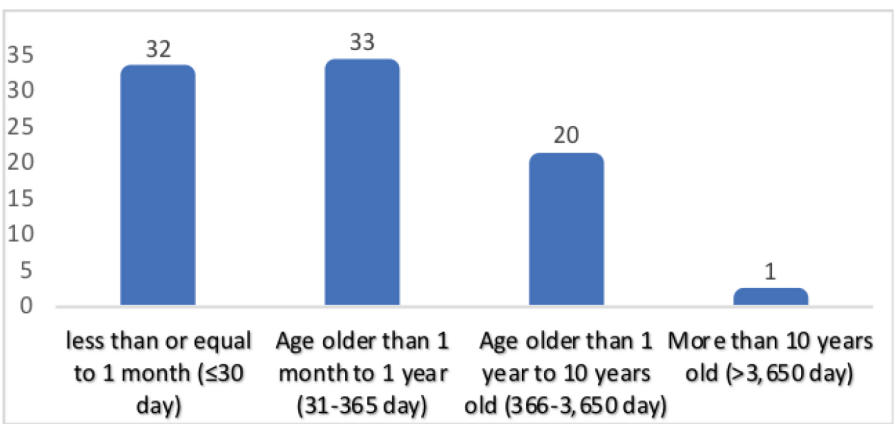

Figure 1 Age distribution of patients

Comparison of pre- and postoperative oxygen saturation

Postoperative blood oxygen levels significantly increased compared to preoperative levels, with a statistical significance of $P < 0.01$ for both procedures: modified Blalock-Taussig-Thomas shunt and modified Waterston shunt. In contrast, the postoperative blood oxygen levels for both the central shunt and modified Pott's shunt procedures did not show a statistically significant difference from preoperative levels (shown in Table 2).

Table 2 Oxygen saturation level in the pre- and post-operative period

Operation	O_2 Sat Pre-operation	O_2 Sat Post-operation	*P*-Value
mBTTS	77.89%	87.32%	< 0.01
mWTS	77.12%	88.58%	< 0.01
CentralS	77.2%	72.8%	0.49
mPottS	83%	85%	**

** The correlation and t cannot be computed because the sum of case weights is less than or equal to 1.

In the modified Blalock-Taussig-Thomas shunt procedure, there were 43 elective cases with no 30-day mortality. However, among the 13 emergency cases, the 30-day mortality was 15.4%. For the modified Waterston shunt procedure, there were 13 elective cases, resulting in a 30-day mortality of 2 patients (15.4%). In contrast, among the 11 emergency cases, there was 1 patient who died within 30 days (9.1%). Lastly, all 4 emergency cases resulted in 30-day mortality in the central shunt procedure. Overall, among the 86 patients with congenital cyanotic heart disease who underwent palliative shunt surgery, there were 9 deaths within 30 days, resulting in a mortality rate of 10.5% (shown in Table 3).

Table 3 Elective and emergency cases with 30-day mortality

Operation	Total	Elective case	Elective case dead	Emergency case	Emergency case dead	Mortality
mBTS	56	43	0	13	2 (15.4%)	2 (3.6%)
mWTS	24	13	2 (15.4%)	11	1 (9.1%)	3 (12.5%)
CentralS	5	1	0	4	4 (100%)	4 (80%)
mPottS	1	0	0	1	0	0
Total	**86**	**57**	**2**	**29**	**7**	**9 (10.5%)**

Discussion

Palliative shunt surgery is a supportive surgical procedure for pediatric patients with cyanotic congenital heart disease. The modified Blalock-Taussig-Thomas shunt (mBTT shunt), introduced in 1981, has been widely employed for various cyanotic congenital heart diseases with increased pulmonary blood flow[8] and has remained a popular surgical intervention. This procedure has proven effective in treating pediatric patients with pulmonary atresia. However, in cases of severe cyanotic congenital heart disease, the shunt serves to facilitate blood flow to the lungs, thereby reducing cyanosis in patients and allowing time to prepare for corrective surgery in the future.

In our institution, the mBTT shunt has demonstrated a low mortality rate because it effectively provides adequate pulmonary blood flow and is simple to construct and take down for total corrective procedures.[9,10]

Research has identified several factors influencing mortality following mBTT shunt surgery in pediatric patients with congenital heart disease. These factors include low birth weight, underlying genetic syndromes, duct dependency, and an oversized shunt relative to the patient's weight.[11] Additionally, studies indicate that the primary causes of postoperative complications and mortality after shunt placement are shunt occlusion and pulmonary overcirculation, which occur due to an excessively large shunt size.[12]

Research from Oman[y] offers recommendations for reducing postoperative mortality rates. It emphasizes the importance of appropriate patient selection for surgery, choosing a suitably sized shunt, and effectively administering anticoagulant therapy.

Our study evaluates the 30-day postoperative mortality rate to identify differences between elective and emergency surgical cases. The study focuses on four key types of procedures involving blood shunt placement to the pulmonary arteries, commonly performed in patients with congenital heart defects and reduced pulmonary blood flow. This categorization aims to better understand the associated risk factors and outcomes.

Emergency case surgeries in critically ill patients generally have higher mortality rates compared to elective surgeries. Similarly, the modified Blalock-Taussig-Thomas shunt (mBTTS) procedure in emergency cases has a higher mortality rate compared to elective cases (15.4% vs. 0%), as does the central shunt procedure (100% vs. 0%).

Conversely, the modified Waterston shunt (mWTS) procedure shows a lower mortality rate in emergency cases compared to elective cases (9.1% vs. 15.4%), while the modified Pott shunt (mPottS) procedure has no reported mortality. However, the latter observation is based on only a single patient undergoing this type of surgery.

The data suggest the following:

1. The mBTTS procedure is associated with a higher survival rate in elective cases.
2. The mWTS procedure may be a more favorable option in emergencies.
3. Future studies should investigate the lower mortality rate of the mWTS procedure in emergency cases compared to elective cases.

Conclusion

This research focuses on palliative shunt surgical procedures in pediatric patients, aiming to provide guidance for reducing morbidity and mortality rates. The modified Blalock-Taussig-Thomas shunt (mBTT shunt) is the most commonly performed procedure and shows a lower 30-day mortality rate compared with other procedures, both in elective and emergency cases.

Limitations

This study may be limited by a small sample size and data collection from only a single institution.

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