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Referral Patterns, Co-occurring Conditions and Survival Outcomes of Biliary Atresia in Thailand: A Data Mining Study from the National Health Security Office Registry

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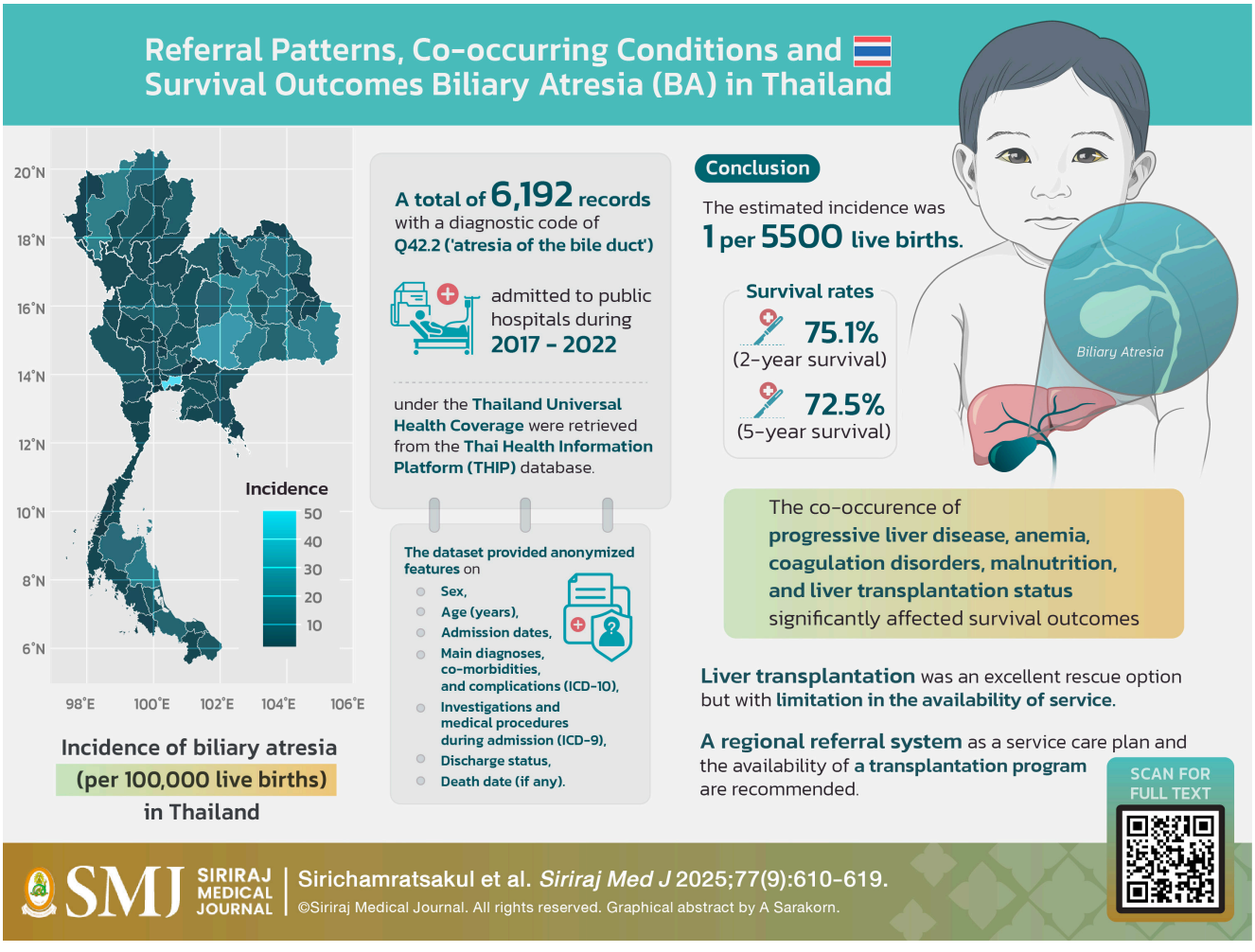

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ABSTRACT

Objective: This study aimed to identify comorbidities and referral patterns in biliary atresia (BA) patients and analyze their influence on survival outcomes using a large national reimbursement cohort.

Materials and Methods: Data were extracted from the National Health Security Office (NHSO) registry via the Thai Health Information Portal (THIP). Patients under six years with a diagnosis of BA between 2017 and 2022 were included. Comorbidities, referral patterns, and survival were analyzed; association rule analysis was performed using the mlxtend package in Python 3.9, whereas survival analysis was conducted using the Kaplan-Meier survival curve.

Results: In total, 957 BA cases among 4,168 admissions were included. The estimated annual incidence was 108.7 cases (1.8 per 10,000 live births). The 2- and 5-year survival rates were 75.1% and 72.5%, respectively. Association rules analysis revealed that metabolic disorders, liver cirrhosis, and portal hypertension had a high confidence of co-occurrence with BA. Anemia, coagulation disorders, malnutrition, liver cirrhosis, hepatic failure, ascites, and hypoalbuminemia were significantly associated with poorer survival outcomes. Cases with more than one referral before a definitive surgery significantly had poorer survival outcomes.

Conclusion: Overall, BA patients in Thailand had fair survival rates. Co-occurring progressive liver diseases, anemia, coagulation disorders, malnutrition, and prolonged referrals significantly contribute to poorer survival. Managing these peri-operative factors might improve the outcome of this devastating disease.

Keywords: Biliary atresia; children; infants; survival; Thailand (Siriraj Med J 2025; 77: 610-619)

INTRODUCTION

Biliary atresia (BA) is a rare yet significant condition that may lead to liver failure and mortality in infants.[1] Its incidence varies across the globe, affecting 1 in 14,000–20,000 live births in Europe and 1 in 16,000–20,000 live births in Canada and the USA.[2] In East Asian countries, BA is more prevalent, affecting around 1 in 5,000–9,600 live births.[3] The etiology of BA remains unclear. However, its mainstay pathology is progressive severe sclerosing inflammation of the bile ducts at the porta hepatis, leading to periportal fibrosis, complete biliary obstruction at the hepatic outflow, and biliary cirrhosis. Surgical restoration of bile flow by a Kasai hepatoportoenterostomy (KPE) is the current standard intervention, with liver transplantation (OLT) considered in cases of late presentation or severe decompensation of liver functions.[4,5]

Approximately half of BA patients survive ten years post-KPE with their native liver.[6] Immediate bile flow restoration following KPE is the most influencing determinant of survival in BA patients. Reported biliary drainage after KPE was around 50-60% of cases.[7,8] However, even in the cases that achieved good biliary drainage, inflammation, and cirrhosis might slowly progress with a consequence such as portal hypertension, malnutrition, failure to thrive, and death.[9] Surveillance and proper management of comorbidities are of primarily important in the postoperative period. Considering surgical quality improvement purposes, a multi-institutional registry should be conducted for a rare disease like BA and other rare congenital anomalies. In Thailand, almost all cases suspected of BA were referred for definitive treatment at a tertiary-level public hospital. There is currently no successful registry at the national level for BA in the country, and the dataset that might be the nearest to the population level is the reimbursement registry of the National Health Security Office Registry (NHSO) data. The dataset includes all admissions in the country, spanning the 6-year period from 2017-2022, with accurate survival status. This analysis used data mining tools to analyze the incidence, co-occurring diagnosis, referral patterns, and survival outcomes of BA cases in Thailand. In addition, associations between co-morbidities and survival were analyzed.

MATERIALS AND METHODS

This retrospective cohort study utilized data mining techniques on data extracted from the reimbursement data repository of the NHSO through the Thai Health Information Platform (THIP), with permission from the local ethics committee (Human Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University, REC.66-529-10-1).

Data source

A total of 6,192 records with a diagnostic code of Q42.2 ('atresia of the bile duct') admitted to public hospitals under the Thailand Universal Health Coverage (UHC) scheme were retrieved from the database. THIP was a joint project between the Institute of Research and Development for Health of Southern Thailand and

the National Science and Technology Development Agency (NSTDA) that archived reimbursement data from the NHSO.[10] When filtering with the patients' age equal to or less than six years, 957 unique cases (4,168 admissions) were included for analysis. The dataset provided anonymized features on sex, age (years), admission dates, main diagnoses, co-morbidities, and complications (ICD-10), investigations and medical procedures during admission (ICD-9), discharge status, and death date (if any). To estimate a population-based incidence rate, we obtained mid-year population data on live births in each district from 2017 to 2022 from the Bureau of Registration Administration, Department of Provincial Administration, Thailand.

Geographical distribution analysis

Geographical distribution was assessed by calculating the average incidence per thousand live births in each district based on each year's average observed incidence and live birth population. Thailand is divided into 76 provinces and 878 administrative districts, with the population of the districts varying from 1,991 to 260,565 and an average population of 50,000. To address the standardized incidence rate, smaller districts were combined with larger ones to form a standardized district (SD), averaging 150,000 people, following Babcock's approach. The baseline district population of the year 2017 was used to account for changes over the study period.

Association rule analysis

To discover the co-occurrence conditions in BA, the Apriori model was used as a data mining algorithm.[11,12] The algorithm uncovers co-occurring diagnoses or complications with the defined diagnosis in terms of the association rule and calculates the likelihood that a condition will be diagnosed given that another item has already been diagnosed and reports as 'confidence'. The analysis used BA (ICD-10 'Q42.2') as the preceding and calculated the 'confidence', 'support', and 'lift' of the co-occurrent conditions. Analysis used the 'association_rules' and the 'apriori' modules of the mlxtend package on Python version 3.9. The threshold used for filtering was a minimum support of 0.05, confidence of at least 0.6, leverage of at least 0, and a lift of at least 1.0.

All co-occurrences were analyzed with survival data using the lifelines package. The p-value threshold for survival analysis was adjusted by the number of all occurrences tested (1,057) by Bonferroni's correction method to be 0.00005 ($5x10^{-5}$). The Manhattan plot was performed with the altair package on Python. The Kaplan-Meier survival curve was constructed on Stata version 14.0 (Stata, TX). All computational codes can be provided on request.

Referral pattern analysis

Cases who did not undergo a KPE (ICD-9 '51.37') on their first admission were regarded as referred cases. Referral duration was the time difference between the first admission when BA was diagnosed and/or the admission when KPE was performed. Survival was compared between cases that underwent an operation on their first admission and those that were referred.

RESULTS

In total, 957 unique cases with the code of BA were recorded among 4,168 admissions during the 6-year period. When filtered by the age criteria, the number of cases aged no more than six years was 750, with 3,349 admissions. The average number of unique cases per year in patients aged < 2 years, likely new cases, was 652, resulting in a crude incidence rate of 18 cases per 100,000 live births. The male-to-female sex ratio was 334:318 or 1.05. The estimated average age on the admission of the patients was 0.17 years or 2 months and the average weight was 3.34 kilograms (standard deviation 2.97). There was recorded mortality in 194 cases in the study period, giving a crude survival rate of 74.1%. When analyzed with a Kaplan-Meier survival estimation, the crude 2-year and 5-year survival rates were 75.1% and 72.5%, respectively.

Associated conditions in BA and their impact on survival

With the conditions described in the method section (support > 0.05, confidence > 0.6, association rule analysis by Apriori algorithm identified 38 significant co-occurrences. After filtering the duplications and unspecific conditions i.e. Fever (R50.9), 16 conditions remained, showing high-confidence associations between BA and metabolic disorders, esophageal varices, cholangitis, liver cirrhosis, and portal hypertension (Table 1). Pre-Kasai cirrhosis occurred in 15.6% of the patients, followed by portal hypertension, coagulation defects, and anemia. At the first admission, esophageal varices and cholangitis were observed in 1.2% and 7.8% of the patients, respectively. Malnutrition and vitamin and mineral deficiencies, particularly vitamin D, hypokalemia, and hyponatremia, were detected in approximately 4-9% of patients at the first admission. Among those with cirrhosis, 236 (67.4%) patients developed cirrhosis since their first admission before the KPE, whereas 101 (29.0%) developed cirrhosis after the KPE. Cholangitis, a major complication of the KPE, occurred in 6.7% of patients with BA at the

TABLE 1. Apriori association rules analysis; biliary atresia-associated conditions that have high support and confidence levels.

ICD-10	Clinical definition	Support	Confidence	Lift
K74.60	Cirrhosis	0.212	0.212	1
K83.0	Cholangitis	0.179	0.179	1
R18	Ascites	0.139	0.139	1
K76.6	Portal hypertension	0.122	0.122	1
E87.6	Hypokalemia	0.092	0.092	1
I85.9	Esophageal varices without bleeding	0.091	0.091	1
E87.1	Hyponatremia	0.084	0.084	1
K74.4	Secondary biliary cirrhosis	0.084	0.084	1
D64.9	Anemia	0.068	0.068	1
I98.2	Esophageal varices in diseases classified elsewhere	0.064	0.064	1
E55.9	Vitamin D deficiency	0.059	0.059	1
Z94.4	Liver transplantation status	0.056	0.056	1
D50.9	Iron deficiency anemia	0.055	0.055	1
D68.9	Coagulation defects	0.055	0.055	1
E44.0	Moderate protein calorie malnutrition	0.055	0.055	1
D62	Acute post-hemorrhagic anemia	0.054	0.054	1

admissions prior to KPE, and 7.1% of patients after the operation. On average, the episode of cholangitis was 2.9 per patient. Cytomegalovirus (CMV) infection was recorded in 8.7% of patients with BA.

On procedural analysis, intraoperative cholangiography (IOC), wedge liver biopsy, and percutaneous liver biopsy were performed primarily in 188 (19.6%), 166 (17.3%), and 101 (10.6%) cases, respectively. During the study period, 287 instances of KPE were recorded, accounting for 44.0% of the estimated number of new cases. Liver transplantation was performed in 109 patients (11.4%), with 76.1% undergoing primary transplants and 23.9% undergoing a transplant after KPE. Primary transplantation was performed in 7.6% of patients with primary cirrhosis of the native liver, which occurred in 24.7% of patients with BA.

Survival analysis by log-rank test was performed for all 1,057 co-occurring diagnoses in 750 cases. Two-year survival was 72.5% (68.9%-75.5%). Using a p-value cutoff at 5 x 10^{-5}, 35 items were considered to have a significant survival impact (Fig 1). Note that the E category (Endocrine, nutritional, and metabolic diseases), K category (Diseases of the digestive system), J category (Diseases of the respiratory system), and D category (anemia and coagulopathy groups) had the highest frequency among conditions with survival impact. Considering together with Apriori co-occurrence analysis, cirrhosis, coagulation defect, electrolyte imbalance (hyponatremia and hypokalemia), ascites, and status post liver transplantation had high support, which meant that they were found as co-occurrences in high incidence and also had significant survival impact (Table 2). Note that transplantation was a protective factor on survival (Hazard ratio 0.11, 95% Confidence interval 0.03-0.34).

Fig 1. Manhattan plot between the ICD-10 categories (Alphabet groups) and -log (p-value) of the log-rank test for significant survival impact.

TABLE 2. Survival probability and Cox's proportional hazard ratio of frequent co-occurrence that significantly had survival impact.

ICD-10	Clinical definition	2-year survival (95% CI)	Hazard ratio (95% CI)
K74.6	Cirrhosis	58.9% (52.9%-64.5%)	2.42 (1.82-3.21)
R18	Ascites	51.8% (41.6%-61.1%)	2.16 (1.57-2.98)
E87.1	Hyponatremia	56.1% (48.5%-63.0%)	2.15 (1.62-2.85)
E87.6	Hypokalemia	54.5% (47.4%-61.1%)	2.51 (1.91-3.32)
E88.0	Hypoalbuminemia	51.7% (42.6%-60.1%)	2.13 (1.57-2.88)
Z94.4	Transplantation status	100% (NA)	0.11 (0.03-0.34)

95% CI: 95% confidence interval, NA: not calculated

Geographical disparities and referrals

At the standardized district (SD) level, Bangkok (BKK), the capital city, had the highest proportion of primary admissions for BA, accounting for 28.7% of the cases, followed by Songkhla (11.3%) and Chiangmai (8.6%) (Fig 2). Annual data revealed that the year 2017 had the highest admission number among the 6-year study period (182, 27.9%), followed by 2018 and 2021 (118, 18.1% and 95, 14.6%, respectively), reflecting the impact of coronavirus disease (COVID-19) pandemic.

When analyzed by health region (HR), the highest number of admissions occurred in HR-13 (Bangkok, 28.7%), followed by HR-12 (Songkhla,11.3%) and HR-1 (Chiang Mai, 8.6%). Within specific SD, the most frequent admissions were in SD-28 (Phaya Thai-Ratchathewi, 14.6%), SD-27 (Bangkok Noi, Bang Plad, 7.5%), and SD-153 (Muang Khon Kaen, 6.1%). Overall, BKK remained the most frequent place of hospitalization for BA, followed by Khon Kaen, Songkhla, and Chiang Mai (Fig 2).

Of the 1,023 referred admissions, patients who were

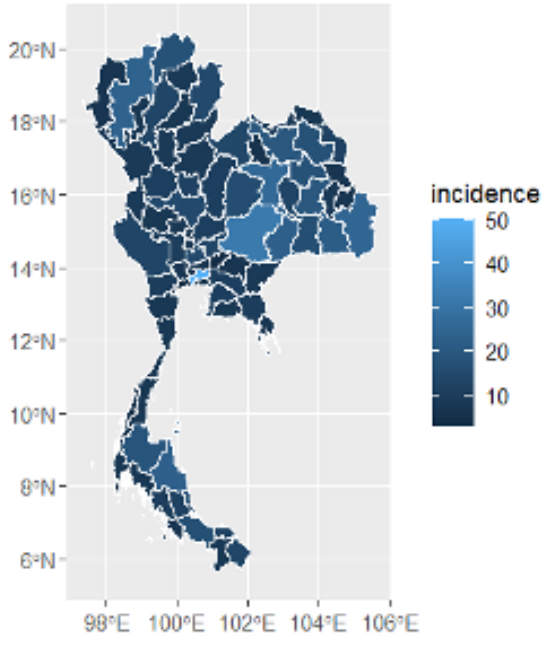

Fig 2. Incidence of biliary atresia (per 100,000 live births) in Thailand, categorized by province of first admission.

primarily admitted to BKK hospitals mostly remained within the BKK referral network (SD-24, SD-27, and SD-28), followed by referrals to SD-153 (Muang Khon Kaen) and SD-242 (Phitsanulok). The average number of visits in each individual patient was 4 (1-36); 5 patients had more than 10 visits, and 3 had more than 30 visits. These three patients with BA underwent KPE and subsequently developed esophageal varices, necessitating multiple visits for esophagogastroduodenoscopy. Additionally, two of these patients experienced multiple episodes of cholangitis requiring hospital admission and antibiotic treatment. Three out of 5 patients still survived with their native livers.

KPE and pre-KPE referral pattern

Of 287 records of KPE, 91 were performed in HR-13 (31.7%), followed by 31 in HR-0 (10.8%), 29 in HR-12 (10.1%), 29 in HR-7 (10.1%), and 20 in HR-2 (7.0%) (Fig 3). Of 287 cases, the surgery was performed on their first admission in 234 cases (81.5%) when 51 (17.7%) had one admission before the definitive surgery and 2 (0.7%) had two prior admissions. In 53 referral cases, the average duration from the first hospital to the hospital where the patients underwent a definitive surgery was 9.2 days (range 1 day - 54 days). Most referrals occurred within the same health region (38 in 53 cases). Among 53 cases, 15 were trans-region referrals, of which 3 were referrals between non-adjacent regions. HR-13 (Bangkok) was the majority of referral destinations (11 in 15 trans-region referrals).

Referred cases had significantly poorer survival outcomes than cases that were operated on in the first hospital they were admitted to. When the two-year overall survival of those who were operated on at the first hospital was 78.26% (95% confidence interval (CI) 72.17% - 83.18%), the figure was 57.13% (95% CI 41.97% - 69.69%) (Log-rank p-value 0.002) in referred cases. (Fig 4)

DISCUSSION

As the first extensive national study to utilize data from the NHSO repository, this study included nearly all patients hospitalized with BA in Thailand, making it an ideal resource for analyzing the spatiotemporal distribution of diseases in the country. The crude incidence of BA in Thailand over the 6-year period was 1 in 5,500 live births, which is similar to that in other parts of Asia and aligns with previously estimated incidences in Thailand that

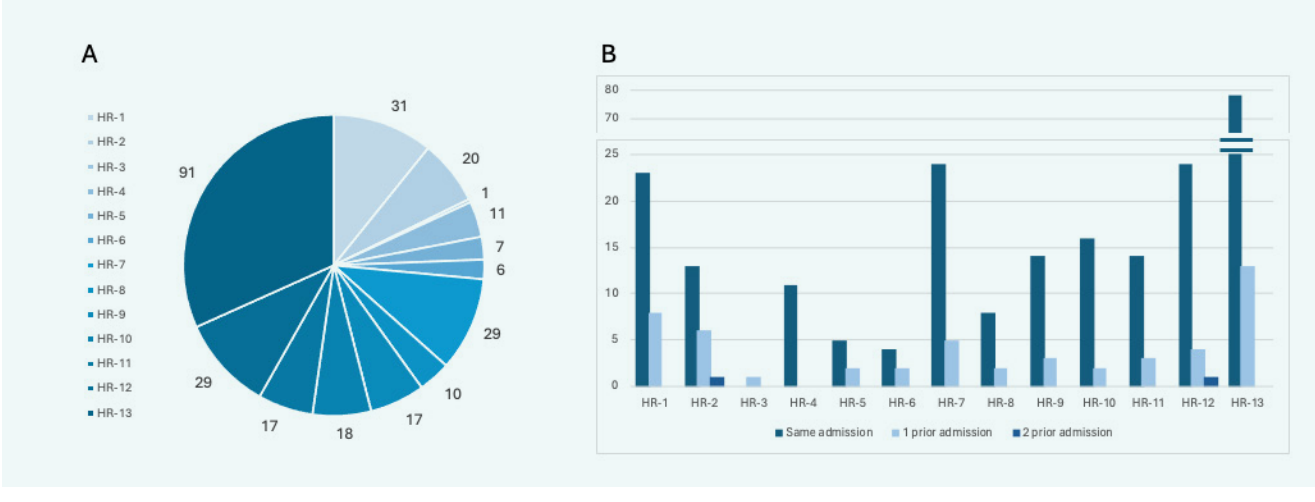

Fig 3. (A) Distribution in the number of Kasai's hepatoportoenterostomy (KPE) operations performed in each health region in Thailand during the study period. (B) Comparing the number of admissions before KPE in each health region.

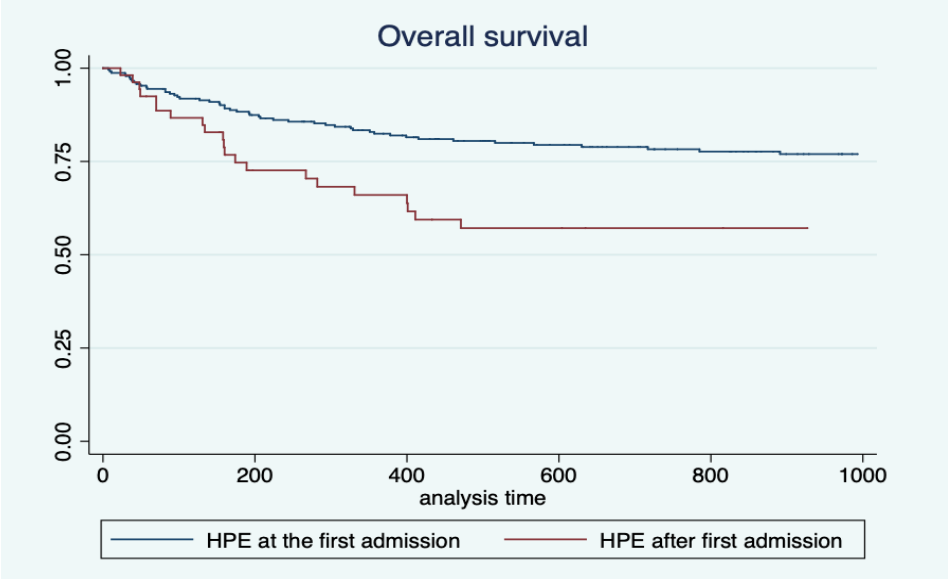

Fig 4. Comparing overall survival between those who underwent a Kasai's hepatoportoenterostomy (KPE) at the first admission and those who were operated on after their first admission.

ranged from 1 in 5,000 to 1 in 15,000 live births[13], but higher than those in Europe, Canada, and the USA.[2,4] The mean age of the patients at presentation was two months, and most of the first admissions occurred in 2017 and 2018, before the COVID-19 pandemic, followed by 2021 in the pandemic era. The COVID-19 pandemic seems to affect BA incidence, possibly due to the decreased accessibility to healthcare services during this period.

In general, diagnosis of BA is confirmed through direct observation of the porta hepatis in cases where an atretic gallbladder is present or via IOC when the findings are not apparent.[14] In our data, IOC was performed in only 19.6% of the cases, which is a notably low number and may be explained by the missing of IOC coding when it was performed as a part of the KPE operation. However, other hospital-based studies in Thailand have reported higher rates of IOC utilization; Chieochalakom et al. observed that all 81% of cholestatic jaundice patients in their study underwent IOC following hepatic scintigraphy or ultrasonography (US) before KPE[14], and Laohapensang et al. reported that 25 of 48 patients in their series (51%) underwent diagnostic IOC. Most omitting cases in their study included 11 patients presenting with atretic gallbladder.[15] Furthermore, Wirifai et al. found that in a tertiary care setting in the North Eastern part of the country, 25 of 26 patients underwent US, 17 of 26 underwent scintigraphy scans, and all patients eventually underwent IOC.[16] Taken together, it seems that the investigation might have been under-recorded rather than under-performed. However, our study advocates a guideline on the preoperative investigation to achieve an accurate diagnosis before a definitive operation.

Our study estimated that KPE was performed in 44% of BA patients in Thailand. The relatively low number of KPE in our data mining could be due to miscoding or overestimating the number of new cases. Another possible explanation was a significant delay in patient presentation, which can negatively affect survival outcomes and increase postoperative morbidity and mortality rates. Consequently, some surgeons discuss the prognosis of the surgery with the parents and opt not to do the surgery. Despite Thai pediatric cholestatic jaundice treatment guidelines recommending KPE before 60 days of age, the mean age at KPE in Thailand was relatively high (82-97 days), given the jaundice onset at around four weeks.[7,14,15,17] In contrast, studies from France, Japan, and Taiwan have reported a median age of 55-59 days for KPE.[1,18,19] We also found that most KPEs were conducted in major tertiary centers in Bangkok, Chiangmai, Khon Kaen, and Songkhla. Additionally, 70.8% of KPEs were performed on the first admission, and those who underwent KPE on subsequent admissions had significantly lower survival rates. This finding aligns with those of previous studies, indicating that the timing of KPE influences survival rates and jaundice clearance.[20,21]

LT was performed in 11.4% of BA patients, which is relatively low considering the success rate of KPE at around 50-60%. Studies from large centers in BKK have shown variable LT volumes, from 4-6 operations per year in each institute.[13,22,23] From 2016 to 2018, 4 pediatric liver transplantation programs in Thailand performed 97 LT operations, and 74% of the patients were diagnosed with BA.[24] In comparison, a USA study reported 441 LDLTs and 611 split deceased-donor LTs

over 12 years[25], and the Japan Liver Transplantation Society (JLTS) reported 2,057 LT operations for BA over 25 years.[26] Due to organ shortages, LDLT is the primary choice of hepatic transplantation in Thailand[13], with 70% of LT performed in BKK and 76.1% of these performed as primary transplants without prior KPE. Considering the referral system, major hospitals in BKK, along with four pediatric LT centers, play a major role in both the KPE and the LT. Large tertiary care centers in the northern, northeastern, and southern regions also contributed substantially to KPE operations. As our study found that referral might cause delays in the treatment and poor operative outcomes, establishing a service care plan for infants with cholestatic jaundice in each HR to shorten the referral path to KPE might improve the overall outcome.

On data mining by the Apriori algorithm, our study identified frequent comorbidities and complications in patients with BA, including anemia and liver-related issues, such as cirrhosis, coagulation defects, and portal hypertension, which affected 10-15% of patients. This suggests late presentation and subsequent delay in the definitive treatment of BA in Thailand. Cholangitis, a major complication of BA, typically occurs within the first year of KPE.[21,27,28] In our study, 6.7% of the admissions of BA in Thailand involved cholangitis, with an average of three episodes per patient. Among these episodes, nearly 10% occurred at the same admission with KPE and 7% on the subsequent admission, with number of episodes ranging from 1 to 9. The co-occurrence of progressive liver diseases (cirrhosis, hepatic failure, or portal hypertension), anemia, coagulation disorders, and malnutrition and liver transplantation status significantly affected survival outcomes. Cirrhosis occurred in 15.6% of patients, with 25% developing cirrhosis at the same admission of KPE and 92% before LT. Similar findings have been reported previously, with portal hypertension and cholangitis affecting a significant proportion of patients during long-term follow-up.[29-31]

The 2- and 5-year estimated survival rates in this study were 75.1% and 72.5%, respectively, which were consistent with previous reports. A large European study reported 5-year native liver survival rates of 41-55% and 10-year survival rates of 35–47% after KPE.[21] Japanese data indicated 5-, 10-, and 20-year survival rates of 63%, 54%, and 44%, respectively, with half of the patients developing cirrhosis by the age of 20 years.[32] A previous Thai study found that 66.3% of patients were alive with jaundice-free status with their native livers over a mean follow-up of 50.5 months.[33]

In summary, our study used data mining to study BA in a large reimbursement dataset in Thailand. The incidence rates of BA in Thailand were comparable to those in other Asian countries, and patients with BA in Thailand exhibit notably lower survival rates. The co-occurrence of progressive liver disease (cirrhosis, hepatic failure, or portal hypertension), anemia, coagulation disorders, and malnutrition, significantly contribute to poor survival outcomes. LT was an excellent rescue option but with limitation in the availability of service. A regional referral system as a service care plan and the availability of a transplantation program are recommended.

Data Availability Statement

The data used in this study was obtained from the Thai Health Information Portal (THIP) database, which registers national health records for individuals admitted to public hospitals in Thailand. Access to this data was approved through THIP's official data access procedures. Due to restrictions on patient privacy, the data is not publicly available but can be requested from the THIP with appropriate permissions.

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DECLARATION

Grants and Funding Information

No funding was received for this study.

Conflict of Interest

No financial or non-financial benefits have been received or will be received from any party related directly or indirectly to the subject of this article.

Registration Number of Clinical Trial

Not applicable.

Author Contributions

K.S. ; Main author, data management, data analysis, and discussion. S.S. ; Co-author, data analysis. V.C. ; Co-author, data management. All the authors contributed to the conception and design of the study and approved the final version for publication.

Use of Artificial Intelligence

No artificial intelligence was used in this study.

Abbreviations

BA – Biliary atresia, KPE – Kasai hepatic portoenterostomy, THIP – Thai Health Information Portal, NHSO – National Health Security Office, UHC – Universal Health Coverage, LT – Liver transplantation, SD – Super-district, HR – Health region, BKK – Bangkok, ICD-10 - 10th revision of the International Classification of Diseases, CMV – Cytomegalovirus, US – Ultrasonography, IOC – Intraoperative cholangiogram

Ethics Approval and Consent to Participate

This study was approved by the Songklanagarind Ethical Committee (Reference No. REC.66-529-10-1) and conducted in compliance with the Helsinki Declaration. The data used was obtained from the Thai Health Information Portal (THIP), which is a national database that records hospital admissions. Since the data was de-identified and extracted from a government health data warehouse, individual patient consent was not required.

Human Ethics and Consent to Participate Declarations

Not applicable.

Consent for Publication

Not applicable. This study used anonymized, de-identified data from the Thai Health Information Portal (THIP) database. No individual-level patient data, images, or details requiring consent for publication are included.

REFERENCES

1. Davenport M. Biliary atresia: clinical aspects. Semin Pediatr Surg. 2012;21(3):175-84.
2. Schreiber RA, Harpavat S, Hulscher JBF, Wildhaber BE. Biliary Atresia in 2021: Epidemiology, Screening and Public Policy. J Clin Med. 2022;11(4).
3. Cavallo L, Kovar EM, Aqul A, McLoughlin L, Mittal NK, Rodriguez-Baez N, et al. The Epidemiology of Biliary Atresia: Exploring the Role of Developmental Factors on Birth Prevalence. J Pediatr. 2022;246:89-94 e2.
4. Hopkins PC, Yazigi N, Nylund CM. Incidence of Biliary Atresia and Timing of Hepatoportoenterostomy in the United States. J Pediatr. 2017;187:253-7.
5. Nakayama DK. Morio Kasai Corrects the Uncorrectable: Hepatic Portoenterostomy for Biliary Atresia. J Pediatr Surg. 2024:161765.
6. Nio M, Ohi R, Miyano T, Saeki M, Shiraki K, Tanaka K, et al. Five- and 10-year survival rates after surgery for biliary atresia: a report from the Japanese Biliary Atresia Registry. J Pediatr Surg. 2003;38(7):997-1000.
7. Sangkhathat S, Patrapinyokul S, Tadtayathikom K, Osatakul S. Peri-operative factors predicting the outcome of hepatic porto-enterostomy in infants with biliary atresia. J Med Assoc Thai. 2003;86(3):224-31.
8. Davenport M, Ong E, Sharif K, Alizai N, McClean P, Hadzic N, et al. Biliary atresia in England and Wales: results of centralization and new benchmark. J Pediatr Surg. 2011;46(9):1689-94.
9. Tomita H, Shimojima N, Sasaki H, Shimotakahara A, Yamada Y, Kuroda T, et al. Predicting Cirrhosis and Poor Outcomes of Bile Drainage Surgery for Biliary Atresia: A Multicentric Observational Study in Japan. Ann Surg. 2024;279(4):692-8.
10. Sirichamratsakul K, Laochareonsuk W, Surachat K, Sangkhathat S. Population-based prevalence study of common congenital malformations of the alimentary tract and abdominal wall in Thailand: a study using data from the National Health Security Office. World J Pediatr Surg. 2023;6(3):e000540.
11. Wu WT, Li YJ, Feng AZ, Li L, Huang T, Xu AD, et al. Data mining in clinical big data: the frequently used databases, steps, and methodological models. Mil Med Res. 2021;8(1):44.
12. Ma H, Ding J, Liu M, Liu Y. Connections between Various Disorders: Combination Pattern Mining Using Apriori Algorithm Based on Diagnosis Information from Electronic Medical Records. Biomed Res Int. 2022;2022:2199317.
13. Arpornsujaritkun N, Leelaudomlipi S, Sobhonslidsuk A, Mingphruedhi S, Jongjirasiri S, Intraprasong P, et al. Outcome of Living Donor Hepatectomy for Pediatric Liver Transplantation: Report of 100 Cases at Ramathibodi Hospital. Rama Med J. 2016;39:217-24.
14. Chieochalakom E, Chiengkriwate P. The Diagnostic Accuracy of Hepatobiliary Scintigraphy and Ultrasonography in Cholestatic Jaundice Infants. Songkla Med J. 2014;32(3):129-37.
15. Laohapensang M, Srikuancharoen P. The Relationship between Clinical Outcomes After Kasai Operation and Related Factors in Infants with Biliary Atresia. J Med Assoc Thai. 2017;100 (Suppl. 4):S99-104.
16. Wirifai T, Laohawilai S. Outcomes of Kasai Operation for Treatment of Patients with Biliary Atresia at a Tertiary Care Hospital. J Dep Med Serv. 2020;45(4):32-6.
17. Sangkhathat S, Laochareonsuk W, Maneechay W, Kayasut K, Chiengkriwate P. Variants Associated with Infantile Cholestatic Syndromes Detected in Extrahepatic Biliary Atresia by Whole Exome Studies: A 20-Case Series from Thailand. J Pediatr Genet. 2018;7(2):67-73.
18. Nio M, Sasaki H, Wada M, Kazama T, Nishi K, Tanaka H. Impact of age at Kasai operation on short- and long-term outcomes of type III biliary atresia at a single institution. J Pediatr Surg. 2010;45(12):2361-3.
19. Fanna M, Masson G, Capito C, Girard M, Guerin F, Hermeziu B, et al. Management of Biliary Atresia in France 1986 to 2015: Long-term Results. J Pediatr Gastroenterol Nutr. 2019;69(4): 416-24.
20. Tessier MEM, Shneider BL. 60 Days in Biliary Atresia: A Historical Dogma Challenged. Clin Liver Dis (Hoboken). 2020;15(Suppl 1):S3-S7.
21. Hukkinen M, Ruuska S, Pihlajoki M, Kyronlahti A, Pakarinen MP. Long-term outcomes of biliary atresia patients surviving with their native livers. Best Pract Res Clin Gastroenterol. 2022;56-57:101764.
22. Choungboonsri C. Does Kasai operation prior to liver transplantation affect peri-operative outcomes in children with biliary atresia? Chulalongkorn Med J. 2021;65(1):45-9.
23. Sihaklang B, Getsuwan S, Pattanaprateep O, Butsriphum N, Lertudomphonwanit C, Tanpowpong P, et al. Cost-effectiveness analysis of liver transplantation in biliary atresia according to the severity of end-stage liver disease. BMC Pediatr. 2023;23(1): 439.
24. Gesprasert G, Chongsrisawat V, Tantemsapya N, Thirapattaraphan

C, Nonthasoot B, Tovikkai C, et al. The first report of pediatric liver transplantation in Thailand from the Thai liver transplant registry. Transplantation. 2020;104(S3):S536.
25. Anouti A, Patel MS, VanWagner LB, Lee WM, Fung JJ, Cholankeril G, et al. Biliary atresia and liver transplantation in the United States: A contemporary analysis. Liver Int. 2023;43(10):2198-209.
26. Umeshita K, Eguchi S, Egawa H, Haga H, Kasahara M, Kokudo N, et al. Liver transplantation in Japan: Registry by the Japanese Liver Transplantation Society. Hepatol Res. 2019;49(9):964-80.
27. Ginstrom DA, Hukkinen M, Kivisaari R, Pakarinen MP. Biliary Atresia-associated Cholangitis: The Central Role and Effective Management of Bile Lakes. J Pediatr Gastroenterol Nutr. 2019;68(4):488-94.
28. Burns J, Davenport M. Adjuvant treatments for biliary atresia. Transl Pediatr. 2020;9(3):253-65.
29. Lykavieris P, Chardot C, Sokhn M, Gauthier F, Valayer J, Bernard O. Outcome in adulthood of biliary atresia: a study of 63 patients who survived for over 20 years with their native liver. Hepatology. 2005;41(2):366-71.
30. Jung E, Park WH, Choi SO. Late complications and current status of long-term survivals over 10 years after Kasai portoenterostomy. J Korean Surg Soc. 2011;81(4):271-5.
31. de Vries W, Homan-Van der Veen J, Hulscher JB, Hoekstra-Weebers JE, Houwen RH, Verkade HJ, et al. Twenty-year transplant-free survival rate among patients with biliary atresia. Clin Gastroenterol Hepatol. 2011;9(12):1086-91.
32. Qisthi SA, Saragih DSP, Sutowo DW, Sirait DN, Imelda P, Kencana SMS, et al. Prognostic Factors for Survival of Patients with Biliary Atresia Following Kasai Surgery. Kobe J Med Sci. 2020;66(2):E56-E60.
33. Laohapensang M, Srikuancharoen P, Tantemsapya N. Factors Related to the Clinical Outcomes of the Kasai Procedure in Infants with Biliary Atresia. Siriraj Med J. 2020;72(3):226-37.
34. Analysis of sequential secondary cytogenetic changes in Ewing's sarcoma: A xenotransplantation model. Virchows Arch. 2005;447(2):494-.

Colorectal Neoplasms in Young Vietnamese Individuals with First-degree Relatives Diagnosed with Colorectal Cancer

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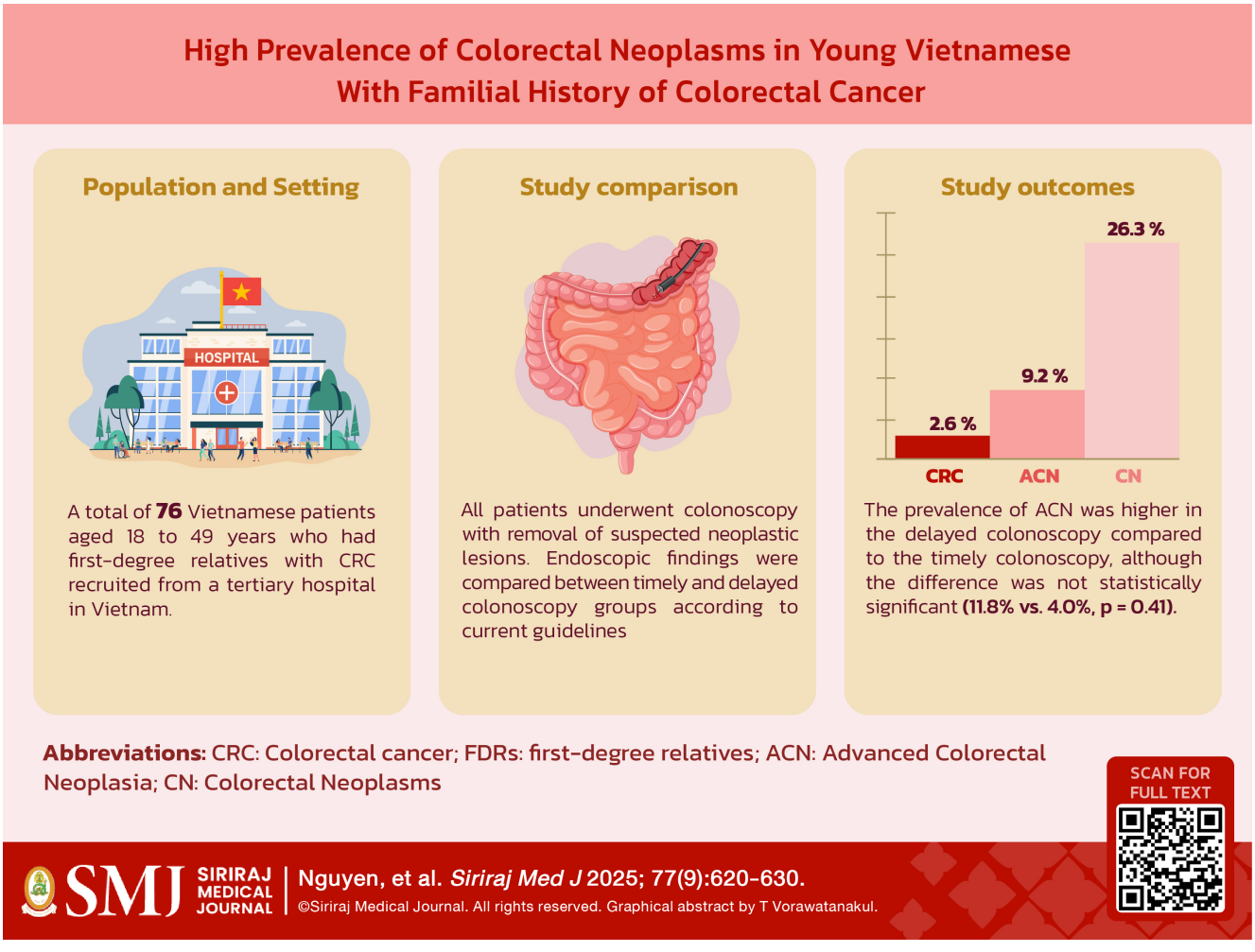

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ABSTRACT

Objective: Colorectal cancer (CRC) is increasingly prevalent, particularly among individuals with first-degree relatives (FDRs) diagnosed with CRC. Delayed colonoscopy beyond the recommended age increases the risk of advanced neoplasia and late-stage CRC. This study aims to characterize colorectal neoplasms in adults under 50 years of age with an FDR history of CRC.

Materials and Methods: A cross-sectional study was conducted on outpatients aged 18–49 years with an FDR history of CRC who presented with lower gastrointestinal symptoms and underwent colonoscopy at a tertiary hospital in Vietnam. All endoscopic lesions suspected of colorectal neoplasia were removed and subsequently reviewed for histopathological examination.

Results: Among 76 patients with FDRs diagnosed with CRC, the mean age was 40.2 ± 6.5 years, with a male-to-female ratio of 1:1.3. A total of 27 neoplastic lesions were identified in 20 patients, including 22 adenomas (81.5%), 3 sessile serrated lesions (11.1%), and 2 adenocarcinomas (7.4%). Overall, colorectal neoplasms were detected in 26.3% (20/76) of patients, with advanced colorectal neoplasia accounting for 9.2% (7/76), including 2.6% (2/76) adenocarcinomas. The incidence of advanced colorectal neoplasms was higher but not significantly different in the delayed colonoscopy group than in the screening group in terms of adherence to the guidelines (11.8% vs. 4%, p = 0.41).

Conclusion: The prevalence of colorectal neoplasms in young Vietnamese individuals with an FDR history of CRC is significantly high.

Keywords: Colorectal cancer; advanced colorectal neoplasms; first-degree relatives; delayed screening (Siriraj Med J 2025; 77: 620-630)

INTRODUCTION

Colorectal cancer (CRC) is one of the most common cancers, ranking third in prevalence and second in mortality worldwide, with an increasing trend in younger populations.[1] A recent American Cancer Society study highlighted that the proportion of CRC diagnoses in individuals under 55 nearly doubled in the United States, rising from 11% in 1995 to 20% in 2019.[2] Similarly, in East Asia, the incidence of CRC among individuals under 50 has been increasing at an annual rate of approximately 1.5%.[3] In Vietnam, early-onset CRC (diagnosed under age 50) accounts for 28% of cases, with familial CRC history being more prevalent in early-onset cases than in late-onset cases.[4]

This growing burden of early-onset CRC may be partially explained by hereditary conditions such as Lynch syndrome, which accounts for 15–17% of cases,[5] while other cases involve familial risks without a clear genetic etiology.[6,7] These findings suggest that early-onset CRC may arise from complex genetic predispositions distinct from the somatic mutations commonly observed in older patients.[6,7] Evidently, a Korean study reported adjusted hazard ratios (HRs) of 1.46 and 1.61 for CRC in individuals with affected parents or siblings, rising to 2.34 when both were affected.[8] In a Hong Kong case–control study, asymptomatic siblings of CRC patients had a threefold higher prevalence of advanced neoplasms (7.5%) than did controls (2.9%).[9] A 16-country Asia–Pacific study reported significantly higher adjusted odds ratios (ORs) for CRC (2.02–7.89), advanced neoplasms (1.55–2.06), and adenomas (1.31–1.92) among those with FDRs diagnosed with CRC.[10]

Delayed colonoscopy screening in FDRs of CRC patients significantly increases the risk of advanced neoplasm and late-stage CRC, particularly in younger adults (<50 years), with studies showing up to a 1.90-fold higher risk and substantial reductions in life-years gained.[11] Studies have consistently shown that delays in CRC diagnosis are linked to an increased likelihood of advanced-stage (stage III or IV) disease, especially in adults under 50 years of age.[12-14] Given the increasing incidence and substantial familial risk associated with early-onset CRC, further research focusing on individuals with FDRs diagnosed with CRC is essential. This study aims to describe the clinical characteristics, endoscopic features, and histopathological findings of colorectal neoplasms in young adults under 50 with an FDR history of CRC.

MATERIALS AND METHODS

Study participants

A cross-sectional study was conducted from March 2022 to December 2023 at the University Medical Center in Ho Chi Minh City, Vietnam. The study included

outpatients aged 18–49 years who presented with lower gastrointestinal symptoms and had an FDR of CRC and underwent colonoscopy. The exclusion criteria included a history of colorectal surgery, inflammatory bowel disease (IBD), inherited cancer syndromes, coagulation disorders, inadequate bowel preparation (Boston Bowel Preparation Scale total score < 6 and/or any regional score < 2), incomplete colonoscopy, withdrawal time of less than 6 minutes, and unwillingness to participate.

Demographic, clinical, endoscopic, and pathologic data were collected and analyzed. Smoking status was categorized as "non-smoker" or "smoker." Overweight/Obesity was defined as a body mass index (BMI) of 23.0 kg/m² or higher for Asia.[15] Non-alcohol consumption was defined as either never drinking or consuming alcohol once a month or less.[16] A family history of CRC was defined as the presence of at least one FDR diagnosed with CRC. All eligible patients provided written informed consent before participation. The study protocol received approval from the Ethics Committee for Biomedical Research at the University of Medicine and Pharmacy in Ho Chi Minh City (Approval ID: 615/HDDD-DHYD, dated November 19, 2021).

Sample size consideration

For sample size calculations, we used the prevalence of colorectal neoplasms at 24%, as observed in a recent Vietnamese study involving the sibling group of individuals aged ≤50 years with early-onset advanced adenoma.[17] Using a 95% confidence level (Z = 1.96) and a margin of error (d) = 0.10, the minimum sample size was calculated according to the formula for estimating a proportion: $n = (Z^2 \times p \times (1 - p)) / d^2$, resulting in a sample size of approximately 70 participants.

Colonoscopy procedure

Bowel preparation was carried out using 3 liters of polyethylene glycol-based solution (Fortrans®, Beaufour Ipsen Industrie, France). The colonoscopies were performed by experienced endoscopists using the Olympus Evis Exera III High Definition CV-190 system (Olympus Co., Ltd., Tokyo, Japan). All endoscopists had an adenoma detection rate of over 30% and had completed at least 3,000 colonoscopic procedures within the past five years. All endoscopically detected lesion morphologies, locations, and sizes were prospectively recorded and analyzed. The polyp macroscopic type was divided into three categories according to the Paris classification: type 0-I: polypoid (0-Is: sessile, 0-Ip: pedunculated); type 0-II: nonpolypoid (0-IIa: slightly elevated, 0-IIb: flat, 0-IIc: slightly depressed); and type 0-III: excavated.[18] Morphologic classification of advanced colorectal cancers was based on the Japanese Classification of Colorectal Carcinoma (JCGA/JSCCR), in which gross tumor types are categorized as polypoid (Type 1), ulcerated with clear or infiltrative margins (Types 2 and 3), diffusely infiltrative (Type 4), or unclassified (Type 5).[19] The proximal colon included the cecum, ascending colon, hepatic flexure, and transverse colon, whereas the distal colon included the splenic flexure, descending colon, sigmoid colon, and rectum.

All the endoscopic lesions were categorized into four types according to JNET classification (1, 2A, 2B, and 3) based on vessel and surface patterns. Vessel patterns include invisible (type 1), regular caliber/regular distribution (type 2A), variable caliber/irregular distribution (type 2B), and loose vessel areas/interruption of thick vessels (type 3). Surface patterns progress from regular dark or white spots (type 1) to regular (tubular/branched/papillary) (type 2A), irregular (type 2B), and amorphous areas (type 3).[20] All lesions suspected of colorectal neoplasia were removed. The suspected invasive cancer lesions were biopsied, and the surgical decision was made based on the pathology results.

With respect to adhering to current guidelines for performing colonoscopy for patients who have FDRs diagnosed with CRC,[21,22] this study defined two concepts: "timely colonoscopy," including individuals who underwent colonoscopy by guidelines, initiating at or before age 40 or at least 10 years earlier than the youngest affected family member's age at diagnosis; and "delayed colonoscopy," comprising those who failed to meet these recommended timelines.

Histopathological analysis

Resected specimens were preserved in 10% buffered formalin, embedded in paraffin, and evaluated by an experienced gastrointestinal pathologist (H.M.L.). Adenomas were classified following the World Health Organization guidelines.[23] Advanced colorectal neoplasia (ACN) lesions were defined as either cancer or sessile serrated lesions with dysplasia or adenomas that were at least 10 mm in size, exhibited high-grade dysplasia, had villous or tubulovillous histology, or a combination of these features.

Statistical analysis

All the statistical analyses were conducted via SPSS software version 20 (SPSS Inc., Chicago, IL). The Kolmogorov–Smirnov test was applied to assess the normality of continuous variables. For variables with a nonnormal distribution, the median and interquartile range (upper and lower quartiles) were reported. Categorical variables are presented as frequencies and percentages.

RESULTS

Participant characteristics

82 patients aged 18–49 with lower gastrointestinal symptoms and an FDR history of CRC were referred for colonoscopy. Among these patients, six were excluded because of a history of colorectal surgery, IBD, or failure to provide informed consent. The analysis included 76 individuals with at least one FDR diagnosed with CRC (Fig 1). A total of 27 neoplastic lesions were detected in 20 individuals, comprising 22 adenomas (81.5%), three sessile serrated lesions (11.1%), and two adenocarcinomas (7.4%).

Among the 76 cases, the most common symptoms were abdominal pain (64.5%) and diarrhea (55.3%), followed by constipation (25.0%), while alarming symptoms like weight loss and hematochezia were less common (7.9% and 2.6%, respectively). The majority of participants (93.4%) had one FDR with CRC, most commonly siblings (56.6%), and a small number had both parents and siblings affected (3.9%). Of the relatives diagnosed with CRC, 27.1% were diagnosed before age 50, as presented in Table 1.

Table 2 summarizes the endoscopic and histological characteristics of colorectal neoplasia lesions. Sessile polyps (0-Is) were the most common lesion shape (70.4%), followed by pedunculated polyps (0-Ip) at 22.2% and flat elevated lesions (0-IIa) at 7.4%, with no depressed lesions (0-IIb) observed. Among the 27 lesions with histopathological results, adenomas were the most prevalent, comprising 81.5% (22/27). Of these, most were tubular adenomas (77.8%, 21/27), with only one case identified as a tubulovillous adenoma. Sessile serrated lesions were observed in 11.1% (3/27). Additionally, two cases (7.4%) were histologically diagnosed as adenocarcinomas. The characteristics of these two adenocarcinoma cases are presented in Table 4 and Fig 2.

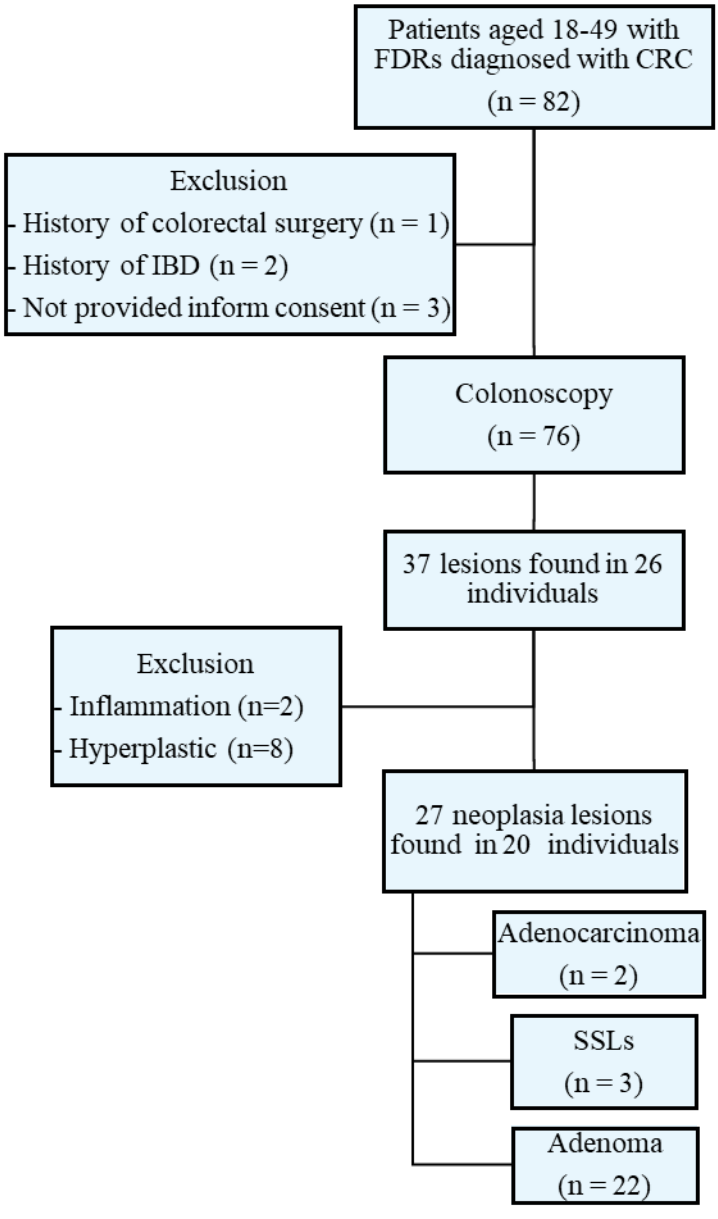

Fig 1. Flow chart of participant recruitment.
Abbreviations: IBD: Inflammatory bowel disease; SSLs: Sessile serrated lesions

TABLE 1. Demographic characteristics of the participants.

Characteristics	FDR, n (%) N = 76
Age	
< 30	4 (5.3)
30 – 39	25 (32.9)
40 – 49	47 (61.8)
Sex (n, %)	
Male	33 (43.4)
Female	43 (56.5)
BMI	
Normal	36 (47.4)
Overweight/Obese	40 (52.6)
Hypertension (n, %)	8 (10.5)
Diabetes (n, %)	3 (3.9)
Smoking (n, %)	16 (21.1)
Alcohol (n, %)	15 (19.7)
Symptoms (n, %)	
Abdominal pain	49 (64.5)
Diarrhea	42 (55.3)
Constipation	19 (25.0)
Weight loss	2 (2.6)
Hematochezia	6 (7.9)
Alarming features	
Weight loss	2 (2.6)
Hematochezia	6 (7.9)
Number of FDRs with CRC diagnosis	
One member	71 (93.4)
Two members	5 (6.6)
Relationship	
Siblings	43 (56.6)
Parents	30 (39.5)
Parents and siblings	3 (3.9)
Age of diagnosis of CRC of FRD	
< 50	22 (27.1)
≥ 50	59 (72.9)

Abbreviations: BMI: Body mass index; CRC: Colorectal cancer; FDRs: First-degree relatives

TABLE 2. Endoscopic and histological characteristics of colorectal neoplasms.

Endoscopic characteristics	N= 27 (%)
Lesion numbers in individuals	20
1	16 (80.0)
2	2 (10.0)
3	1 (10.0)
4	1 (10.0)
Size	
≤ 5 mm	13 (48.1)
6 - 9 mm	4 (14.8)
10 – 19 mm	9 (33.3)
≥ 20 mm	1 (3.7)
JNET classification	
JNET 1	7 (26.0)
JNET 2A	18 (66.6)
JNET 2B	2 (7.4)
Shape (Paris classification)	
0-Is	18 (66.7)
0-Ip	5 (18.5)
0-IIa	2 (7.4)
0-IIb	0 (0.0)
Type 1 (Japanese Classification of CRC)	2 (7.4)
Location	
Proximal	14 (51.8)
Distal	13 (48.2)
Treatment methods	
Biopsy or CSP	11 (40.7)
HSP	12 (44.4)
EMR	2 (7.4)
ESD	0 (0.0)
Surgery	2 (7.4)
Histological characteristics	
Adenoma	22
Tubular adenoma with low-grade dysplasia	21 (77.8)
Tubular villous adenoma with low-grade dysplasia	1 (3.7)
Traditional serrated adenoma	0 (0.0)
Sessile serrated lesion	1 (3.7)
Sessile serrated lesion with dysplasia	2 (7.4)
Adenocarcinoma	2 (7.4)
Advanced colorectal neoplasia	8 (29.6)

Abbreviations: JNET: Japan NBI Expert Team, EMR: Endoscopic mucosal resection, ESD: Endoscopic submucosal resection, CSP: Cold Snare Polypectomy, HSP: Hot Snare Polypectomy

TABLE 3. Association between clinicopathologic characteristics and the occurrence of advanced colorectal neoplasia (ACN).

Characteristics	Non ACN (n = 69)	ACN (n = 7)	p value
Age ≥ 40 (%)	41 (59.4)	6 (85.7)	0.241
Number of FDRs with CRC ≥ 2 (%)	2 (2.9)	3 (42.9)	0.005
Youngest FDR diagnosed <50 (%)	15 (21.7)	3 (42.9)	0.346
Hematochezia (%)	4 (5.8)	2 (28.6)	0.092
Weight loss (%)	2 (2.9)	0 (0.0)	1
Delay colonoscopy	45 (65.2)	6 (85.7)	0.415

Abbreviations: FDRs: First-degree relatives; CRC: Colorectal cancer; ACN: Advanced colorectal neoplasia

TABLE 4. Demographic, endoscopic, and histological characteristics of two patients diagnosed with colorectal adenocarcinoma.

Characteristics	Patient 1	Patient 2
Age	43	45
Sex	Male	Male
Smoking	Yes	Yes
Overweight/Obese	Yes	Yes
Alarming signs	No	No
Number of FDRs of CRC	2	2
Relationship of FDR	Parent and sibling	Parent and sibling
Age of the youngest FDR diagnosed with colorectal cancer	54	49
Symptoms	Diarrhea	Abdominal pain
Alarming signs	No	No
Adhering to colorectal screening guidelines	Delayed colonoscopy (3 years)	Delayed colonoscopy (5 years)
Lesions		
Location	Rectum	Sigmoid colon
Size (mm)	15	25
Shape	Type 1	Type 1
Treatment modality	Low anterior resection	Left hemicolectomy
Pathology	Moderately differentiated carcinoma	Moderately differentiated carcinoma from tubular villous adenoma
Invasion	Muscularis propria	Submucosa
Diagnosis	pT2N0M0	pT1N0M0

Abbreviations: FDRs: First-degree relatives, CRC: Colorectal cancer

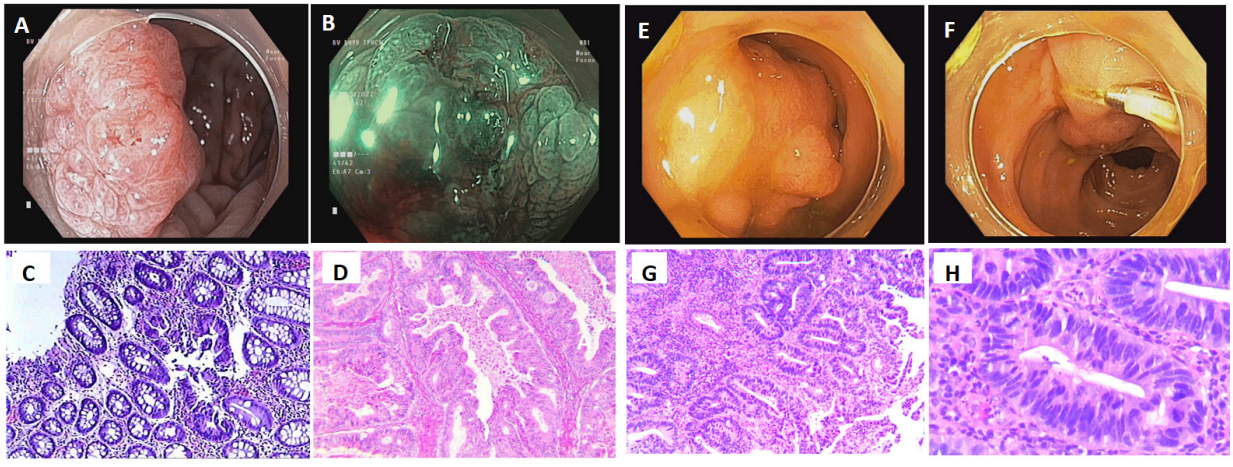

Fig 2. Endoscopic and histological findings of two adenocarcinoma lesions. Lesion 1: A type 1 lesion in the rectum was observed in white light endoscopy (A), and narrow-band imaging (B) showed JNET 2B. Histological images 10x (C) and (D) showed moderately differentiated adenocarcinoma with muscularis propria invasion; (C) from the biopsy specimen and (D) from the surgical resection. Lesion 2: A type 1 lesion in the sigmoid colon was observed in white light endoscopy (E), and another 0-Ip advanced adenoma was found in the sigmoid colon (F). Histological figures 10x (G) and 40x (H) confirmed that moderately differentiated adenocarcinoma arose in a tubular villous adenoma with deep submucosal invasion.

Table 3 shows the relationship between ACN and several clinicopathologic characteristics. Patients with two or more FDRs diagnosed with CRC had a significantly higher rate of ACN (42.9% vs. 2.9%, p = 0.005). Other factors, such as being aged 40 or older, having a youngest affected FDR aged under 50, the presence of hematochezia, and delayed colonoscopy, were more common among individuals with ACN. However, these differences were not statistically significant.

Overall, among the 76 participants, 26.3% (20/76) had colorectal neoplasms, 9.2% (7/76) had ACN lesions, and 2.6% (2/76) were diagnosed with adenocarcinoma. The occurrence of ACN lesions was higher in the delayed colonoscopy group than in the group that adhered to the guidelines, with rates of 11.8% and 4%, respectively (p value = 0.41), but the difference was not statistically significant.

DISCUSSION

This study highlighted the clinical, endoscopic, and histopathological findings of colorectal neoplasms in individuals under 50 with an FDR history of CRC. Currently, limited data exists on colorectal neoplasia lesions in this population across Asian countries, particularly in Vietnam. Our study revealed that 26.3% (20/76), 9.2% (7/76), and 2.6% (2/76) of the patients had neoplasia lesions, ACN lesions, and adenocarcinoma, respectively. When these findings were compared with those of a screening program in 1,404 individuals in Thailand, which included 117 patients of all ages with FDRs diagnosed with CRC, the detection rates were 11.1% for neoplasia lesions, 3.4% for ACN lesions, and 3.4% for CRC.[24] Similarly, in a prospective cross-sectional study in Hong Kong, ACN lesions and CRC were detected in siblings of patients with CRC at rates of 7.5% (28/374) and 1.6% (6/374), respectively, which were relatively higher than those in controls in the average group.[9] The rates of ACN lesions and CRC in studies from Thailand and Hong Kong are lower than our findings. Nevertheless, our study focused on those under 50 years of age, suggesting a higher detection rate in our younger population. The rate of early-onset CRC in Vietnam was 28%, with a significantly greater prevalence of familial CRC in the early-onset group than in the late-onset group (21.4% vs. 7.6%, p < 0.001).[4] Similarly, in this series of cases, we observed a nearly identical rate of CRC diagnoses in relatives before age 50, at 27.1% (22/81), which is consistent with earlier findings.

In a screening program in Australia, the data for 485 patients under 50 showed that the detection rates were 16.5% for neoplastic lesions, 4.3% for ACN lesions, and 1% for adenocarcinomas.[25] Similarly, a study from Korea reported detection rates of 19.5% for neoplasia lesions, 1.9% for ACN lesions, and 0.8% for CRC among 570 individuals under 50.[26] Although these two studies did not focus on individuals with FDRs diagnosed with CRC, and thus cannot be directly compared. However, the rates of advanced lesions and CRC in our study (9,2%) were higher than those reported in these studies, emphasizing the increased risk among those with a

family history of CRC. Our study is the first to evaluate the prevalence of colorectal neoplasms in this specific population. While comparisons with other studies are indirect, these findings offer insight into the influence of having FDRs on the occurrence of colorectal lesions in individuals under 50.

Regarding delayed screening in our study, the incidence of ACN lesions was higher in the "delayed colonoscopy" group than in the "timely colonoscopy" group at 11.8% versus 4%, respectively. Given the limited number of ACN cases and the small overall sample size, this subgroup analysis was underpowered to detect statistically significant differences and should be considered exploratory. Further research with a larger cohort is needed to better clarify these relationships. This is particularly important, as previous studies have demonstrated a high rate of early-onset CRC in Vietnam, especially among individuals with an FDR history of CRC, who should adhere strictly to recommended screening timelines.[4] A large multicenter cross-sectional study by Quintero et al. assessed the risk of advanced neoplasia in FDRs of patients with CRC. This study revealed that delayed screening in FDRs in individuals with two FDRs diagnosed with CRC was associated with a 1.90-fold increased risk, with an OR of 1.90 (95% CI: 1.36–2.66), of developing advanced neoplasia compared with the average risk group.[11] Several studies have reported that delays in the diagnosis of CRC are associated with increased odds of being diagnosed at an advanced stage (stage III or IV), particularly in younger adults (<50 years).[12-14] A systematic review of 39 studies, which included 185,710 younger and 1,422,062 older CRC patients, evaluated clinical delays and outcomes between these age groups. Sixteen studies examining prediagnostic intervals consistently reported longer delays for younger adults, who also had significantly higher odds of presenting with advanced-stage CRC, with a pooled OR of 1.76 (95% CI: 1.52–2.03).[13] A simulation study by Rutter et al. found that a 5-year delay in screening initiation increased the incidence of CRC by 21.7% and that of late-stage CRC by 26.8%, with a 12.4% reduction in life-years gained.[14] Delayed colonoscopy in high-risk individuals may not only increase the likelihood of detecting CRC at a more advanced stage but also affect postoperative recovery and quality of life. A recent study conducted in Thailand highlighted the influence of psychosocial and socioeconomic factors, such as financial strain, limited familial support, and heightened anxiety, on the postoperative well-being of CRC patients. These findings emphasize the critical importance of timely screening and comprehensive, patient-centered care, particularly among younger individuals with a significant familial predisposition.[27] Timely colonoscopic evaluation may have facilitated earlier detection and enabled the endoscopic removal of precancerous or early-stage lesions. This aligns with findings from Mongkhonsupphawan et al., who reported a 5-year overall survival rate of 70.9% among stage I–III CRC patients undergoing curative resection in Thailand. Furthermore, rectal cancer was associated with less favorable prognoses compared to colon cancer, with distant recurrence observed in up to 28.6% of rectal cancer cases.[28] Therefore, early sigmoidoscopic screening also holds promise in detecting neoplastic lesions in the rectum at an earlier, more treatable stage.

Our study identified two cases of adenocarcinoma in patients who underwent colonoscopy later than the recommended age; both had exceeded the indications for endoscopic intervention. If these two lesions had been screened earlier, they could have been completely removed via endoscopic resection. These two cases share the common characteristic of early-onset CRC, with the prevalent anatomic site in the distal colon (50%-80% of cases).[7] Among the 143 immigrant Asian CRC patients included in the retrospective review, Lynch syndrome was identified in 4.19% of them. In the Lynch group, two-thirds of the tumors were located on the left side of the colon, similar to the distribution observed in the sporadic CRC group.[29] CRC associated with Lynch syndrome in Asian individuals is predominantly observed in the distal colon, a distribution pattern that aligns with findings in sporadic CRC patients. Therefore, if individuals with an FDR of CRC are not prepared for colonoscopy, sigmoidoscopy could be considered an alternative screening option to detect early lesions and encourage them to proceed with a complete colonoscopy. Since their young age at diagnosis (43 and 45 years) and the presence of CRC in both a parent and a sibling, these two patients may fulfill clinical criteria for hereditary colorectal cancer syndromes such as Lynch syndrome. According to international guidelines—including the National Comprehensive Cancer Network (NCCN)[30] and the European Society for Medical Oncology (ESMO)[31] recommend that patients diagnosed with CRC before age 50, particularly those with two or more FDRs affected (regardless of age), be referred for genetic counseling and germline testing, ideally using multigene panels. In our study, neither patient underwent molecular or genetic testing, which highlights a significant gap in how hereditary cancer risk is currently assessed in our healthcare setting. Although access to genetic testing in Vietnam is still limited, expanding its availability and improving awareness of guideline-based evaluations for Lynch syndrome and other inherited CRC syndromes

should be a key priority. This is an important step forward in improving patient care and preventing cancer in high-risk families.

This study has several limitations. First, it was conducted at a single tertiary center with a relatively small sample size, which may limit the generalizability of the findings. Second, we did not include a comparison group of individuals without a family history of CRC, which restricts our ability to assess relative risk. Third, although two young patients with multiple affected relatives met criteria for genetic evaluation, germline testing was not performed, reflecting the limited availability of such services in our setting.

In conclusion, our study identified neoplasia lesions in 26.3% of patients, advanced colorectal neoplasia in 9.2%, and colorectal cancer in 2.6% of young Vietnamese individuals with FDRs diagnosed with CRC. Two cases of CRC in this series were delayed-screened according to the guidelines' recommendations, which have been proven to be associated with increased odds of being diagnosed at an advanced stage.

Data Availability Statement

All the data generated or analyzed during this study are included in this published article. Further inquiries can be directed to the corresponding author.

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Conflict of Interest

The authors declare no conflicts of interest. All the authors involved in this article reviewed and approved the final version of the manuscript.

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Author Contributions

Conceptualization and methodology, D.T.Q.; Investigation, D.T.N.N., N.T.H.V., M.N.L., Q.D.L., T.L.T.T., V.L.T.T.; Histological analysis, H.M.L.; Supervision and critical revision, D.T.Q.; Writing – original draft, D.T.N.N.; Writing – review and editing, D.T.Q. All authors have read and approved the final version of the manuscript.

Use of Artificial Intelligence

Artificial intelligence tools (ChatGPT by OpenAI) were used to improve the manuscript's language, structure, and clarity. All authors reviewed and approved the final content.

Statement of Ethics

The study protocol complies with the ethical principles outlined in the 1975 Helsinki Declaration. The study received approval from the Ethics Committee in Biomedical Research at the University of Medicine and Pharmacy in Ho Chi Minh City, Vietnam (Approval ID: 615/HDDD-DHYD, dated November 19, 2021). Written informed consent was obtained from all participants and/or their legal guardians.

REFERENCES

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021;71(3):209-49.
2. Siegel RL, Wagle NS, Cercek A, Smith RA, Jemal A. Colorectal cancer statistics, 2023. CA Cancer J Clin. 2023;73(3):233-54.
3. Huang J, Lucero-Prisno DE, 3rd, Zhang L, Xu W, Wong SH, Ng SC, et al. Updated epidemiology of gastrointestinal cancers in East Asia. Nat Rev Gastroenterol Hepatol. 2023;20(5):271-87.
4. Quach DT, Nguyen OT. Clinical, endoscopic and pathogical characteristics of early-onset colorectal cancer in Vietnamese. Asian Pac J Cancer Prev. 2012;13(5):1767-70.
5. Pearlman R, Frankel WL, Swanson B, Zhao W, Yilmaz A, Miller K, et al. Prevalence and Spectrum of Germline Cancer Susceptibility Gene Mutations Among Patients With Early-Onset Colorectal Cancer. JAMA Oncol. 2017;3(4):464-71.
6. Silla IO, Rueda D, Rodríguez Y, García JL, de la Cruz Vigo F, Perea J. Early-onset colorectal cancer: a separate subset of colorectal cancer. World J Gastroenterol. 2014;20(46):17288-96.
7. Stigliano V, Sanchez-Mete L, Martayan A, Anti M. Early-onset colorectal cancer: a sporadic or inherited disease? World J Gastroenterol. 2014;20(35):12420-30.
8. Jung YS, Song H, Tran MTX, Park B, Moon CM. Association between A Family History of Colorectal Cancer and the Risk of Colorectal Cancer: A Nationwide Population-Based Study. J Pers Med. 2022;12(10):1566.
9. Ng SC, Lau JY, Chan FK, Suen BY, Leung WK, Tse YK, et al. Increased risk of advanced neoplasms among asymptomatic siblings of patients with colorectal cancer. Gastroenterology. 2013;144(3):544-50.
10. Wong MC, Ching JY, Chiu HM, Wu KC, Rerknimitr R, Li J, et al. Risk of Colorectal Neoplasia in Individuals With Self-Reported Family History: A Prospective Colonoscopy Study f rom 16 Asia-Pacific Regions. Am J Gastroenterol. 2016;111(11):1621-9.

11. Quintero E, Carrillo M, Leoz ML, Cubiella J, Gargallo C, Lanas A, et al. Risk of Advanced Neoplasia in First-Degree Relatives with Colorectal Cancer: A Large Multicenter Cross-Sectional Study. PLoS Med. 2016;13(5):e1002008.
12. Lee YH, Kung PT, Wang YH, Kuo WY, Kao SL, Tsai WC. Effect of length of time from diagnosis to treatment on colorectal cancer survival: A population-based study. PloS One. 2019;14(1):e0210465.
13. Castelo M, Sue-Chue-Lam C, Paszat L, Scheer AS, Hansen BE, Kishibe T, et al. Clinical Delays and Comparative Outcomes in Younger and Older Adults with Colorectal Cancer: A Systematic Review. Curr Oncol. 2022;29(11):8609-25.
14. Rutter CM, Inadomi JM, Maerzluft CE. The impact of cumulative colorectal cancer screening delays: A simulation study. J Med Screen. 2022;29(2):92-8.
15. Consultation WE. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157-63.
16. Knott CS, Coombs N, Stamatakis E, Biddulph JP. All cause mortality and the case for age specific alcohol consumption guidelines: pooled analyses of up to 10 population based cohorts. BMJ. 2015;350:h384.
17. Luan Minh Dang, Nhan Quang Le, Huy Minh Le, Diem Thi-Ngoc Vo, Nguyen Lam Vuong, Minh Cuong Duong, et al. Risk of Advanced Adenomas in Siblings Aged ≤ 50 Years of Patients with Early-Onset Colorectal Advanced Adenomas. Dig Dis Sci. 2025.
18. Group. ECR. Update on the paris classification of superficial neoplastic lesions in the digestive tract. Endoscopy. 2005;37(6):570-8.
19. Rectum JSfCotCa. Japanese Classification of Colorectal, Appendiceal, and Anal Carcinoma: the 3rd English Edition [Secondary Publication]. J Anus Rectum Colon. 2019;3(4):175-95.
20. Sano Y, Tanaka S, Kudo SE, Saito S, Matsuda T, Wada Y, et al. Narrow-band imaging (NBI) magnifying endoscopic classification of colorectal tumors proposed by the Japan NBI Expert Team. Dig Endosc. 2016;28(5):526-33.
21. Shaukat A, Kahi CJ, Burke CA, Rabeneck L, Sauer BG, Rex DK. ACG Clinical Guidelines: Colorectal Cancer Screening 2021. Am J Gastroenterol. 2021;116(3):458-79.
22. Rex DK, Boland CR, Dominitz JA, Giardiello FM, Johnson DA, Kaltenbach T, et al. Colorectal Cancer Screening: Recommendations for Physicians and Patients from the U.S. Multi-Society Task Force on Colorectal Cancer. Am J Gastroenterol. 2017;112(7):1016-30.
23. Nagtegaal ID, Odze RD, Klimstra D, Paradis V, Rugge M, Schirmacher P, et al. The 2019 WHO classification of tumours of the digestive system. Histopathology. 2020;76(2):182-8.
24. Siripongpreeda B, Mahidol C, Dusitanond N, Sriprayoon T, Muyphuag B, Sricharunrat T, et al. High prevalence of advanced colorectal neoplasia in the Thai population: a prospective screening colonoscopy of 1,404 cases. BMC Gastroenterol. 2016;16(1):101.
25. Wong S, Lidums I, Rosty C, Ruszkiewicz A, Parry S, Win AK, et al. Findings in young adults at colonoscopy from a hospital service database audit. BMC Gastroenterol. 2017;17(1):56.
26. Jeong SJ, Lee J, Kim E, Hwang JS, Lee J, Choi JH, et al. Prevalence and risk of colorectal polyps among the Korean population under 50 years. Medicine. 2022;101(27):e29493.
27. Thongdeebut T, Danaidutsadeekul S, Phligbua W, Lohsiriwat V. Impact of Social Determinants of Health on Postoperative Health-Related Quality of Life Among Patients Undergoing Colorectal Cancer Surgery. Siriraj Med J. 2025;77(5):331-41.
28. Mongkhonsupphawan A, Sethalao N, Riansuwan W. Long-term Oncologic Outcomes After Curative Surgery in Stage I–III Thai Colorectal Cancer Patients. Siriraj Med J. 2022;74(11):739-46.
29. Lee J, Xiao YY, Sun YY, Balderacchi J, Clark B, Desani J, et al. Prevalence and characteristics of hereditary non-polyposis colorectal cancer (HNPCC) syndrome in immigrant Asian colorectal cancer patients. BMC Cancer. 2017;17(1):843.
30. Weiss JM, Gupta S, Burke CA, Axell L, Chen LM, Chung DC, et al. NCCN Guidelines® Insights: Genetic/Familial High-Risk Assessment: Colorectal, Version 1.2021. J Natl Compr Cancer Netw. 2021;19(10):1122-32.
31. Stjepanovic N, Moreira L, Carneiro F, Balaguer F, Cervantes A, Balmaña J, et al. Hereditary gastrointestinal cancers: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up†. Ann Oncol. 2019;30(10):1558-71.

Is It Safe to Perform a Right-sided Laparoscopic Living Donor Nephrectomy Compared to the Open Technique? A Single-center Experience in Thailand

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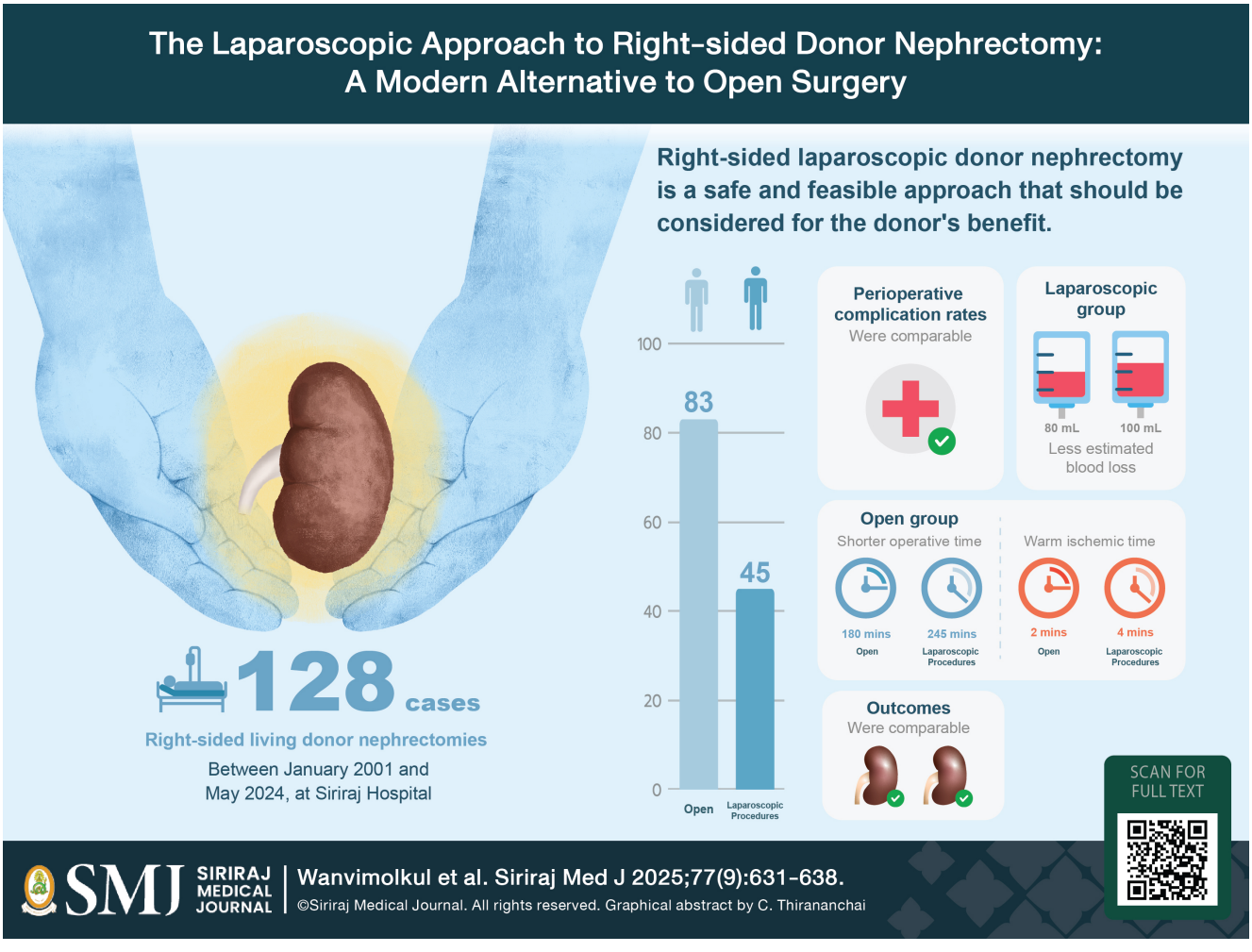

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ABSTRACT

Objective: Living donor kidney transplantation is the treatment of choice for many patients with end-stage renal disease. Laparoscopic donor nephrectomy (LDN) offers the benefits of minimally invasive surgery to donors. However, right-sided LDN continues to raise concerns among some surgeons due to challenges related to donor safety and graft outcomes. This study aims to evaluate the surgical outcomes and graft function associated with right-sided LDN compared to the open donor nephrectomy.

Materials and Methods: Between January 2001 and May 2024, a total of 128 right-sided living donor nephrectomies were performed at Siriraj Hospital, including 83 open and 45 laparoscopic procedures. A comparative analysis was conducted between the two surgical approaches.

Results: The most common indication for right-sided nephrectomy was the presence of multiple or early-branching renal arteries on the left side (62.5%). The estimated blood loss was significantly lower in the laparoscopic group compared to the open group (80 mL vs 100 mL, p=0.004). However, operative and warm ischemic times were significantly longer in the LDN group (245 minutes vs. 180 minutes, $p < 0.001$ and four vs. two minutes, $p < 0.001$, respectively). Perioperative complication rates were comparable between the two groups. Only one case (2.22%) in the LDN group required conversion to open surgery. From the recipient's perspective, renal graft outcomes were comparable, with no instances of acute graft loss in either group.

Conclusion: Based on our evidence, the laparoscopic approach for right-sided donor nephrectomy is both feasible and safe. Right-sided LDN should be considered for its benefits.

Keywords: Right-side donor nephrectomy; Laparoscopic donor nephrectomy; Donor nephrectomy (Siriraj Med J 2025; 77: 631-638)

INTRODUCTION

The introduction of kidney transplantation nearly a century ago marked a transformative milestone in the treatment of end-stage renal disease (ESRD).[1] Initially dependent on deceased donors, the field has since evolved to include living donor transplants. This advancement has been accompanied by improvements in surgical techniques, including laparoscopic procedures, and the development of more effective immunosuppressant therapies. Together, these innovations have significantly enhanced transplant success rates, resulting in better patient outcomes and quality of life.

The global rate of kidney transplantation has been steadily increasing over the years.[2] In Thailand, however, this increase is primarily driven by deceased donor transplants, while the rate of living donor kidney transplantation remains low. This trend persists despite significant benefits, such as a lower risk of delayed graft function (DGF) and improved immediate graft function.[3] Previous studies have shown that the introduction of less invasive surgical techniques, such as laparoscopic approaches, significantly enhances individuals' willingness to become living kidney donors.[4,5]

When selecting a kidney for donation, the primary considerations are the donor's safety and the potential long-term risk of developing end-stage renal disease. If a significant functional disparity exists between the two kidneys, typically defined by a glomerular filtration rate (GFR) difference greater than 10%, the kidney with lower function is typically selected for donation. However, if both kidneys have comparable function, anatomical factors take precedence.[6] Surgeons generally prefer the left kidney for donation due to its longer renal vein, which facilitates the transplantation process. This preference has become more pronounced with the advent of laparoscopic donor nephrectomy (LDN).[7] Nonetheless, the right kidney may be selected in cases where the left kidney has unfavorable anatomical features, such as multiple or complex vascular structures, cysts, or stones.

At the Faculty of Medicine Siriraj Hospital, LDN was first introduced in 2001. Over the following decade, 129 patients underwent laparoscopic kidney donation. The results showed that LDN is both effective and safe, with outcomes comparable to open surgery nephrectomy.[8] Despite the widespread adoption of LDN, concerns remain regarding donor safety and graft outcomes, particularly in right-sided nephrectomies. In real practice, most left-sided donor nephrectomies are performed laparoscopically, while right-sided procedures are more commonly done using the open technique. However, several studies have reported that right-sided LDN achieves success rates comparable to those of left-sided LDN procedures.[9,10] This study aims to compare the surgical outcomes and graft function between right-sided LDN and the open

technique at our institution. The ultimate goal is to promote wider adoption of the laparoscopic approaches for right-sided donor nephrectomy, thereby enhancing donor safety and potentially increasing interest in kidney donation.

MATERIALS AND METHODS

The study protocol was approved by the Institutional Review Board of the Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand, protocol number COA no. Si 578/2024. This study retrospectively reviewed the medical records of 128 patients who underwent right-sided nephrectomy at our institution between January 2001 and May 2024, following the introduction of laparoscopic donor nephrectomy as an option at our center in 2001.

Data were collected from both donor and recipient medical records and included demographic information, indication for right-sided donor nephrectomy, perioperative outcomes, and graft outcomes. Patients were categorized into two groups: LDN and open donor nephrectomy (ODN). Indications for choosing the right kidney included the presence of multiple or early-branching vessels in the left kidney, superior function of the left kidney, or pathological findings in the right kidney. Superior function of the left kidney was defined as a glomerular filtration rate (GFR) difference of more than 10% and DGF was defined as the requirement for dialysis within the first postoperative week.

The ODN procedure was performed using a standard retroperitoneal flank approach without rib resection. LDN was performed via a transperitoneal approach using three or four ports. In the initial eight cases, the kidney was retrieved through a low transverse incision with a hand-assist device. Subsequently, manual extraction was done through a 7–9 cm Pfannenstiel incision. In our cohort, hilar control was achieved using lockable polymer clips.

Quantitative variables such as age, body mass index (BMI), and serum creatinine levels, were reported as mean ± standard deviation for normally distributed variables or as median for non-normally distributed variables. Qualitative data, such as gender and complication rates, were expressed as frequencies and percentages. Comparisons of categorical data were performed using the Chi-square test or Fisher's exact test. Continuous data with normal distribution were analyzed using the Student's t-test and the Mann-Whitney U test for non-normally distributed continuous data. All analyses were conducted using SPSS Version 18 (IBM Corp., Armonk, NY), with a p-value <0.05 considered statistically significant.

RESULTS

A total of 128 right-sided donors were included in this study, with 83 undergoing open ODN and 45 undergoing LDN. The most common indication for right-sided donor nephrectomy was the presence of multiple or early branching arteries on the left side (62.5%), followed by superior function of the left kidney in 25% of cases. Other indications included right-sided renal pathologies, such as renal cysts (6.25%) and small calyceal stones (3.13%), as summarized in Table 1.

Donor demographic data and surgical outcomes for the LDN and open ODN are presented in Table 2. There were no significant differences in baseline characteristics between the two groups, including age, sex, body mass

TABLE 1. Indications for right-sided donor nephrectomy.

Indications (n, %)	No. of Donors (%) (N=128)
Two or more arteries on left side	72 (56.25)
Early branching of left renal artery	8 (6.25)
Better function of left kidney (>10%)	32 (25.00)
Right renal artery stenosis	1 (0.78)
Right renal cyst	8 (6.25)
Small calyceal stone in right kidney	4 (3.13)
Right renal anomaly*	3 (2.34)

*Right double collecting system, malrotation of right kidney, scar of the lower pole of the right kidney

TABLE 2. Donor demographics and surgical outcomes.

Variables	Open nephrectomy (N=83)	Laparoscopic nephrectomy (N=45)	*p*-value
Age (mean±SD, years)	37.90±9.42	36.71±10.98	0.617
Sex (M:F)	33:50	19:26	0.786
BMI (mean±SD, kg/m^2)	24.11±4.20	22.79±3.36	0.071
Preoperative Cr (mean±SD, mL/min)	0.79±0.19	0.80±0.18	0.632
Operative time (Median range, mins)	180 (82,360)	245 (160, 350)	<0.001
Estimated blood loss (Median range, ml)	100 (20, 2,600)	80 (10, 3,000)	0.004
Warm ischemic time (Median range, mins)	2 (0.5, 8)	4 (1.5, 14)	<0.001
Length of stays, (mean±SD, days)	5.99±1.63	6.09±1.71	0.743
Tube drain (N, %)	44 (53.01)	18 (40.00)	0.196
Duration of tube drain (mean±SD, days)	3.05±0.61	3.5±1.38	0.195
Immediate post-operative serum Cr (mean±SD, mL/mins)	1.25±0.32	1.20±0.29	0.355
Cr at discharge (mean±SD, mL/min)	1.12±0.29	1.07±0.26	0.360
Intraoperative complication (N, %)	7 (8.43)	3 (6.67)	0.745
Postoperative complication (N,%)	21 (25.30)	15 (33.33)	0.335

index and preoperative serum creatinine levels, indicating comparable donor profiles. However, significant differences were observed in operative parameters. The median operative time and warm ischemic time were significantly longer in the LDN group compared to the ODN group (245 vs. 180 minutes, $p < 0.001$ and 4 vs. 2 minutes, $p < 0.001$, respectively). Estimated blood loss was significantly lower in the LDN group (80 vs. 100 ml, $p = 0.004$).

Intraoperative complications occurred in 8.4% of ODN cases and 6.6% of LDN. Only one patient (2.22%) in the LDN group required conversion to open surgery due to technical challenges related to poor exposure in a high BMI case. In the ODN group, there were seven complications, including vascular injury, renal injury, and pleural injury; however, the difference between groups was not statistically significant ($p = 0.745$). Postoperative complications were observed in 25.3% of ODN cases and 33.3% of LDN cases, though the difference was not statistically significant ($p = 0.335$). Major postoperative complication, defined as a Clavien-Dindo score greater than three, occurred in only one case in the LDN group. This case, only the third LDN case of our series, involved postoperative bleeding from a renal vein tear that required re-exploration. Among minor complications, fever was the most common and occurred significantly more often in the LDN group (22.2% vs. 7.2%, $p = 0.023$). Surgical site-related complications in ODN group, including surgical site infection and pleural injury, were more frequently observed in the ODN group. Other minor complications, including anemia requiring transfusion, paralytic ileus, acute urinary retention, electrolyte imbalances, phlebitis, and herpes zoster infection, were comparable between the groups (Table 3).

Regarding recipient outcomes, renal graft function was comparable between the two groups. The median vascular anastomosis time did not significantly differ between ODN and LDN groups (41 vs. 43.5 minutes, $p = 0.685$). The incidence of graft-related complications, including acute rejection and ureteric leakage, showed no significant differences. There were no cases of acute graft loss, renal artery thrombosis, or renal vein thrombosis in either group. Although the incidence of DGF was slightly higher in the ODN group, the difference was not statistically significant. Serum creatinine levels at discharge were also comparable between both groups. (Table 4)

TABLE 3. Donor perioperative complications.

Variables (n, %)	Open nephrectomy	Laparoscopic nephrectomy	*p*-value
Intraoperative complications			
Conversion to open	0	1 (2.22)	0.352
Vascular injury	3 (3.61)	2 (4.44)	1.000
Renal injury	2 (2.41)	0	0.540
Pleural injury	2 (2.41)	0	0.540
Postoperative complications			
Major complication			
Postoperative bleeding requires re-exploration	0	1 (2.22)	0.352
Minor complication			
Pneumothorax	3 (3.61)	0	0.551
Surgical site infection	4 (4.82)	1 (2.22)	0.656
Anemia requiring transfusion	3 (3.61)	0	0.551
Paralytics ileus	0	1 (2.22)	0.352
Post-operative fever	6 (7.22)	10 (22.22)	0.023
Acute urinary retention	1 (1.29)	1 (2.22)	1.000
Electrolyte imbalances	3 (3.61)	0	0.551
Phlebitis	0	1 (2.22)	0.351
Herpes zoster infection	1 (1.20)	0	1.000

TABLE 4. Recipients' graft outcomes.

Variables	Open nephrectomy	Laparoscopic nephrectomy	*p*-value
Recipient anastomosis time (Median range, min)	41 (20, 91)	43.5 (11, 70)	0.685
Acute rejection	12 (15.00)	5 (11.36)	0.573
Delayed graft function	8 (10.00)	2 (4.55)	0.492
Ureteric leakage	2 (2.50)	1 (2.27)	1.000
Renal artery thrombosis	0	0	
Renal vein thrombosis	0	0	
Perinephric hematoma	1 (1.25)	0	1.000
Serum Cr at discharge (mean±SD, mL/min)	1.41±0.78	1.50±0.83	0.559

DISCUSSION

The superiority of LDN over ODN has been well established in previous studies, demonstrating advantages such as reduced intraoperative blood loss, shorter hospital stays, decreased postoperative pain, and improved cosmetic outcomes.[8,11-14] However, in most studies, LDN has predominantly been performed on the left side due to the anatomical advantages, including a longer renal vein and the absence of liver mobilization. In contrast, the use of laparoscopic techniques for right-sided donor nephrectomy remains a subject of ongoing debate, particularly regarding its safety and impact on graft outcomes.

Our study specifically focused on right-sided donor nephrectomies, comparing laparoscopic and open approaches. We found that, even on the right side, LDN offered the advantage of significantly reduced blood loss (80 mL vs 100 mL, $p = 0.004$), highlighting one of the key benefits of minimally invasive surgery. Although LDN was associated with longer WIT and operative duration, the WIT remained within an acceptable range (4 minutes), and the operative time observed in our study was consistent with previous literature.[15] Moreover, recent studies have also reported that the operative time for right-sided LDN may be shorter than that for left-sided procedures.[16] In our LDN cohort, the conversion rate to open surgery was 2.22% (1 case), which is consistent with previously reported conversion rates for right-sided LDN, ranging from 1.79% to 6.25%.[17,18] This conversion was due to poor intraoperative exposure. The patient in this case had a BMI of 24.38. Notably, a study by Jacobs et al.[19] showed that markedly obese patients (BMI > 35) undergoing LDN were more likely to require conversion to open nephrectomy compared to donors with ideal body size (7.3% vs. 0%). In our series, we performed LDN in two obese patients (defined as BMI > 30), and neither required conversion or experienced any intraoperative complications. This suggests that the conversion observed in our study was likely attributable to the surgeon's experience.

One of the primary concerns in right-sided LDN is achieving adequate renal vein length while ensuring secure pedicle control. Two commonly employed methods for ligating the renal pedicle include non-transfixing techniques, such as lockable polymer clips, and transfixing techniques like surgical staplers. Although the safety of polymer clips for pedicle control has been questioned, recent studies have demonstrated that they are both safe and effective, and offer additional advantages such as increased vascular length and cost efficiency.[20,21] In our cohort, polymer ligating clips were used for vascular control in all cases, and no instances of clip dislodgement or clip-related complications were observed. As donor safety remains paramount, future developments in surgical instruments like staples designed to preserve greater venous length at a reasonable cost may further optimize outcomes in right-sided LDN.

Previous studies have reported perioperative complication rates ranging from 5% to 30% for LDN, and from 0% to 35% for ODN.[22] In our study, which specifically focused on right-sided donor nephrectomies, the perioperative complication rate for LDN was 40.31%, compared to 33.73% for ODN. Furthermore, we observed no major laparoscopy-specific complications, such as intraabdominal organ injury. Our results demonstrated comparable postoperative complication rates between the two surgical approaches. Most complications in the LDN group were minor, including fever, paralytic ileus, and phlebitis. Only one major complication was observed in the LDN group — postoperative bleeding in the third case, which required re-operation. This may be attributed to our learning curve associated with performing right-sided LDN.

In contrast, the ODN group was associated with more surgical site-related complications, including surgical site infections and pleural injuries. Three cases in the ODN group developed pneumothorax, one of whom required intercostal drainage (CDC grade 3a). Additionally, three cases experienced anemia requiring transfusion. Notably, neither pneumothorax nor transfusion-requiring anemia occurred in the LDN group. There were no cases of mortality among donors undergoing right-sided nephrectomy. While previous studies have reported significantly shorter hospital stays for LDN[14], our cohort showed no significant difference in length of stay between the two approaches. This is likely due to local clinical practice in Thailand, where most patients prefer to remain hospitalized for approximately one week to ensure full recovery before discharge.

In terms of recipient outcomes, concerns have been raised that the laparoscopic approach could compromise graft function due to factors such as pneumoperitoneum, longer WIT, and shorter renal vein length. Although LDN in our study was associated with significantly longer operative time and WIT, the latter remained within an acceptable range of four minutes. Importantly, graft function did not differ significantly between the LDN and ODN groups. Also, anastomosis times were comparable, suggesting that the technical difficulty of vascular anastomosis was not markedly different between the two approaches. Additionally, there were no cases of acute graft loss, renal artery thrombosis, or renal vein

thrombosis in either group. A recent systematic review in 2025 demonstrated that right-sided living donor kidney transplantation is associated with a higher risk of DGF and graft loss compared to left-sided transplantation.[16] However, in our study, the incidence of thrombosis, acute rejection, graft loss, and DGF were all comparable between surgical approaches. The technique of pain management for improving recipient outcomes was also previously reported.[23] Nevertheless, the importance of long-term recipients' outcomes in right-sided donors still needs further investigation.

Nevertheless, the retrospective design of our study presents several limitations. Notably, data on postoperative pain and cosmetic outcomes, which are likely to be more favorable in the LDN — were not available. Additionally, the study was conducted at a single center, where surgeon preference and experience could have influenced the outcomes. The sample size for both surgical approaches was also small. However, to our knowledge, this represents the largest report comparing right-sided donor nephrectomy using both surgical approaches in the Thai population.

CONCLUSION

Our findings suggest that right-sided LDN is as safe as the open approach, given its comparable complication profile. Although LDN is associated with longer operative and warm ischemia times, recipient graft outcomes remain unaffected. Moreover, LDN provides the added benefits of reduced intraoperative blood loss. Therefore, the laparoscopic approach should be considered a viable option even for right-sided nephrectomies. However, further research is needed to validate these findings and to assess long-term outcomes, particularly with respect to postoperative pain, convalescence data, and cosmetic outcomes.

Data Availability Statement

The data supporting this study are available from the corresponding author upon reasonable request.

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DECLARATION

Grants and Funding Information

None.

Conflict of Interests

The authors declare no conflict of interest.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization and methodology: N.W., T.W., T.H.; Investigation: N.W., V.W.; Formal analysis: N.W., P.L.; Visualization and writing—original draft: N.W., T.W.; Writing-review and editing: T.W., E.C., S.J.; Supervision: T.W.

Use of Artificial Intelligence

No artificial intelligence tools or technologies were used in the analysis of the manuscript.

Ethics Statement

The study protocol was approved by the Siriraj Institutional Review Board (SIRB) (COA no. Si 578/2024).

REFERENCES

1. Dash SC, Nair R, Behera V. Kidney transplantation: The journey across a century. Med J Armed Forces India. 2023;79(6):631-7.
2. International report on Organ Donation and transplantation activities 2022 [Internet]. Global Observatory on Donation and Transplantation. 2023. Available from: https://www.transplant-observatory.org/wp-content/uploads/2023/11/2022-data-global-report_VF_2.pdf.
3. Larpparisuth N, Cheungpasitporn W, Lumpaopong A. Global Perspective on Kidney Transplantation: Thailand. Kidney360. 2021;2(7):1163-5.
4. Schweitzer EJ, Wilson J, Jacobs S, Machan CH, Philosophe B, Farney A, et al. Increased rates of donation with laparoscopic donor nephrectomy. Ann Surg. 2000;232(3):392-400.
5. Ratner LE, Hiller J, Sroka M, Weber R, Sikorsky I, Montgomery RA, et al. Laparoscopic live donor nephrectomy removes disincentives to live donation. Transplant Proc. 1997;29(8):3402-3.
6. Gentil Govantes MÁ, Pereira Palomo P. Assessment and selection of kidney living donors. Nefrología. 2010;30 Suppl 2:47-59.
7. Khalil A, Mujtaba MA, Taber TE, Yaqub MS, Goggins W, Powelson J, et al. Trends and outcomes in right vs. left living donor nephrectomy: an analysis of the OPTN/UNOS database of donor and recipient outcomes--should we be doing more right-sided nephrectomies? Clin Transplant. 2016;30(2):145-53.
8. Taweemonkongsap T, Nualyong C, Amornvesukit T, Srinualnad S, Jitpraphai S, Premasathian N, et al. Laparoscopic live-donor nephrectomy: a comparison with the open technique and how to reach quality standards: a single-center experience in Thailand. Transplant Proc. 2011;43(10):3593-8.
9. Tyagi V, Singh M, Pahwa M, Jain S, Chaddha S, Jauhari H. Right Laparoscopic Donor Nephrectomy: A Large-Volume, Single-Center Experience. Exp Clin Transplant. 2021;19(3):217-23.
10. Mohsin R, Shahzad A, Sultan G, Aziz T, Hashmi A. Right Sided Laparoscopic Donor Nephrectomy - Dream Comes True. Transplantation. 2018;102:S505.

11. Flowers JL, Jacobs S, Cho E, Morton A, Rosenberger WF, Evans D, et al. Comparison of open and laparoscopic live donor nephrectomy. Ann Surg. 1997;226(4):483-9; discussion 9-90.
12. Tsoulfas G, Agorastou P, Ko DS, Hertl M, Elias N, Cosimi AB, et al. Laparoscopic vs open donor nephrectomy: Lessons learnt from single academic center experience. World J Nephrol. 2017;6(1):45-52.
13. Gupta N, Raina P, Kumar A. Laparoscopic donor nephrectomy. J Minim Access Surg. 2005;1(4):155-64.
14. Alston C, Spaliviero M, Gill IS. Laparoscopic donor nephrectomy. Urology. 2005;65(5):833-9.
15. Carnabatu C, Tatum D, Paramesh A, Jeon H, Killackey M, Vijay A. Laparoscopic Living Donor Nephrectomy: A Single Center Comparison of Three Different Techniques. JSLS. 2023;27(1):e2022.00088.
16. Calpin GG, Hehir C, Davey MG, MacCurtain BM, Little D, Davis NF. Right and left living donor nephrectomy and operative approach: A systematic review and meta-analysis of donor and recipient outcomes. Transplant Rev (Orlando). 2025;39(1):100880.
17. Ahmadi A, Rashed AAA, Hasan O, Awad N, Abdulaziz K, Turki B, et al. Laparoscopic Right Donor Nephrectomy: A Two-Center Comparative Study. Cureus. 2024;16(5):e59562.
18. Kumar A, Chaturvedi S, Gulia A, Maheshwari R, Dassi V, Desai P. Laparoscopic Live Donor Nephrectomy: Comparison of Outcomes Right Versus Left. Transplant Proc. 2018;50(8):2327-32.
19. Jacobs SC, Cho E, Dunkin BJ, Bartlett ST, Flowers JL, Jarrell B, et al. Laparoscopic nephrectomy in the markedly obese living renal donor. Urology. 2000;56(6):926-9.
20. Lachkar S, Boualaoui I, Ibrahimi A, El Sayegh H, Nouini Y. Clip or staple in laparoscopic live donor nephrectomy? A systematic literature review. Fr J Urol. 2024;34(7-8):102656.
21. Hsi RS, Ojogho ON, Baldwin DD. Analysis of Techniques to Secure the Renal Hilum During Laparoscopic Donor Nephrectomy: Review of the FDA Database. Urology. 2009;74(1):142-7.
22. Skrekas G, Papalois VE, Mitsis M, Hakim NS. Laparoscopic live donor nephrectomy: a step forward in kidney transplantation? JSLS. 2003;7(3):197-206.
23. Boonyapalanant C WV, Jitpraphai S, Chotikawanich E, Taweemonkongsap T, Hari BKC, et al. The Efficacy of Inside-Out Transversus Abdominis Plane Block vs Local Infiltration before Wound Closure in Pain Management after Kidney Transplantation: A Double-blind, Randomized Trial. Siriraj Med J. 2022;74(4):233-8.

Accuracy of Breast Magnetic Resonance Imaging (MRI) and Breast Ultrasound Compared to Pathology in Assessing Residual Tumor in Breast Cancer Patients Receiving Neoadjuvant Systemic Treatment at Siriraj Hospital

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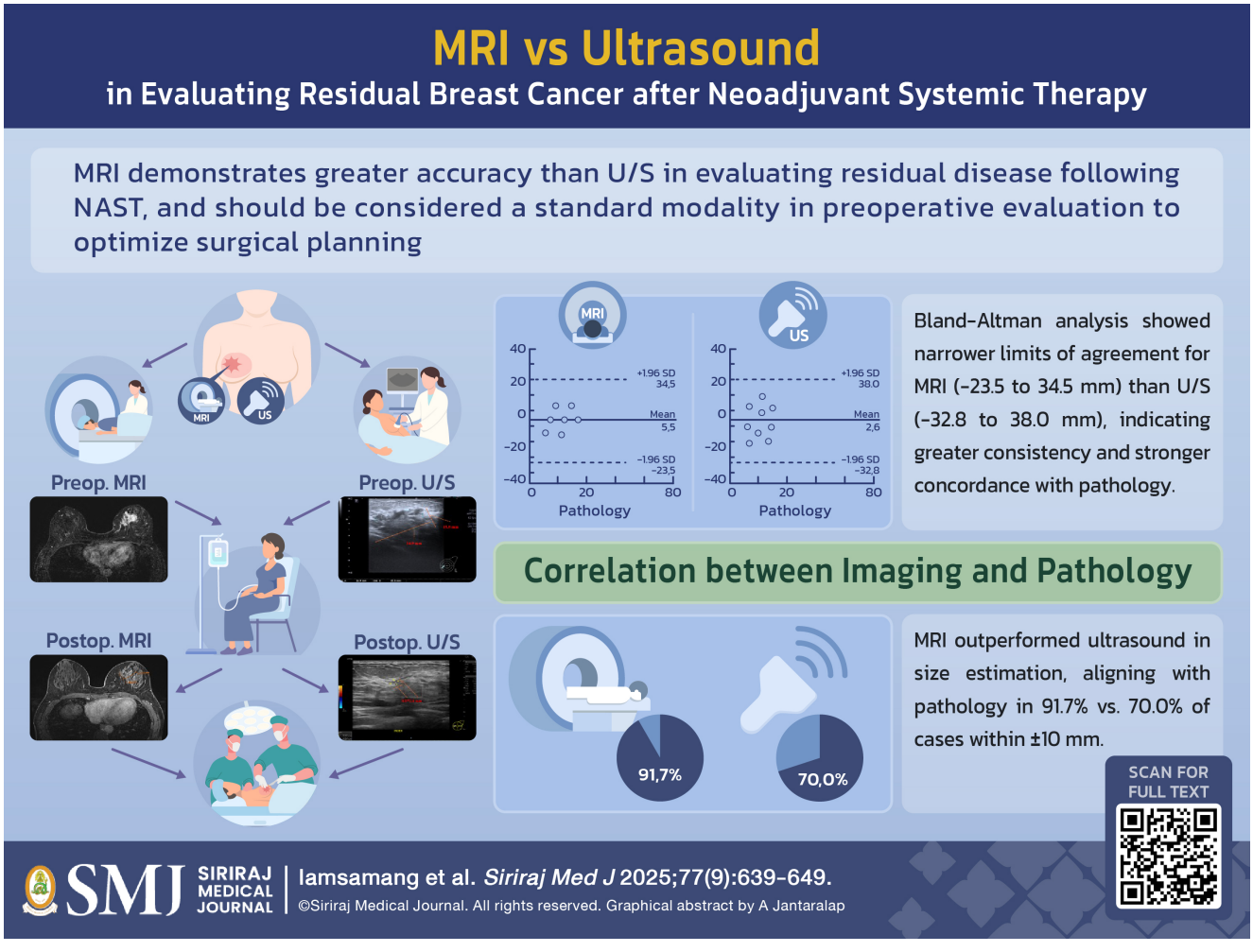

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ABSTRACT

Objective: To evaluate the accuracy of magnetic resonance imaging (MRI) and ultrasound (US) in assessing residual tumor size compared to pathological findings in breast cancer patients who received neoadjuvant systemic treatment (NAST), and to examine the influence of imaging on surgical planning across different molecular subtypes.

Materials and Methods: This retrospective study included 24 breast cancer patients who underwent NAST followed by surgery at Siriraj Hospital between 2016 and 2024. Preoperative breast MRI and breast US, performed within 3–6 weeks prior to surgery, were compared with pathological tumor size. Analysis focused on mass lesions, with non-mass enhancement (NME) considered in selected cases where it presented. Imaging findings were independently reviewed by a second, blinded radiologist. Concordance between imaging and pathology was assessed.

Results: A total 24 patients were analyzed. MRI showed superior agreement with pathological tumor size, with 91.7% of cases falling within a ±10 mm margin, compared to 70.0% for US. Mean tumor sizes were 5.4 mm for MRI, 8.3 mm for US, and 10.9 mm based on pathological examination. Bland-Altman analysis revealed better agreement between MRI and pathology (limits of agreement: –23.5 – 34.5 mm) compared to US. These results highlight the superior accuracy and reliability of MRI over US for preoperative tumor size assessment.

Conclusion: MRI demonstrates greater accuracy than US in evaluating residual disease following NAST. In case of invasive lobular carcinoma (ILC) subtypes, incorporating NME into imaging assessment may improve concordance with pathological findings. MRI should be considered a standard modality in preoperative evaluation to optimize surgical planning.

Keywords: Breast cancer; neoadjuvant chemotherapy; MRI; ultrasound; pathological concordance (Siriraj Med J 2025; 77: 639-649)

INTRODUCTION

Breast cancer is currently the most commonly diagnosed cancer among women, leading to rapid advancements in treatment strategies that markedly differ from those of the past.[1] This is particularly evident for tumors with high proliferative potential, leading to a high likelihood of lymphatic or distant metastasis, such as HER2-positive and triple-negative breast cancer (TNBC), and those with elevated Ki-67 expression.

In most cases, treatment begins with systemic therapy—including chemotherapy, targeted therapy, or immunotherapy—administered before surgery (neoadjuvant systemic treatment, or NAST). Systemic therapy may lead to a clinical complete response (cCR), characterized by the absence of detectable tumor on physical examination, mammography, and ultrasonography. In certain cases, a pathological complete response (pCR), defined as the absence of residual invasive cancer on histopathological assessment, may also be achieved, correlating with improved survival outcomes.[2]

The pattern of tumor shrinkage varies significantly.[3] According to a study by Erika M.S. et al., in patients with mass lesions visible on MRI, the correlation between MRI findings and final pathology was as high as 86%.[4] Most tumors presenting as mass lesions demonstrate concentric shrinkage mode (CSM) in response to NAST, which is more common in TNBC and HER2-positive subtypes. Conversely, tumors, especially the luminal subtype, exhibited on MRI as non-mass enhancement (NME) patterns tend to respond with a scattered shrinkage pattern.[5] These different patterns complicate post-NAST response assessment using mammography or US alone and may lead to positive surgical margins, necessitating reoperation and potentially compromising oncologic outcomes. In luminal tumors, concentric shrinkage is seen in only 45.7% of cases, compared to 66.2% in TNBC and 59% in HER2-positive cases.[6] Accurate preoperative imaging to determine the pattern of response after NAST is therefore critical in optimizing surgical planning and minimizing margin positivity, which is linked to increased local recurrence and reoperation.

MRI is the most sensitive modality for evaluating residual disease after NAST due to its superior contrast resolution and ability to detect NME or scattered tumor foci.[7] However, variability in MRI performance across molecular subtypes—overestimating or underestimating residual disease—highlights the need for further study.

While studies from Western countries and East Asia—including a recent large-scale Korean cohort study by Kim et al.[8]—have investigated the diagnostic accuracy of magnetic resonance imaging (MRI) in predicting pathological complete response (pCR) across molecular subtypes, data from Southeast Asian populations, including Thailand, remain limited. In this region, the

majority of patients present with heterogeneously dense to extremely dense breast tissue, which may impact imaging outcomes. Furthermore, differences in tumor biology, imaging interpretation, access to diagnostic technology, and treatment protocols may influence the diagnostic performance and reliability of MRI in this specific context. The scarcity of locally relevant evidence underscores the need for region-specific validation of imaging strategies in the neoadjuvant setting.

This study aims to evaluate the concordance between preoperative imaging modalities— MRI and US—and final pathological findings in breast cancer patients undergoing NAST at Siriraj Hospital. Additionally, patterns of tumor shrinkage (concentric vs. scattered) are characterized according to molecular subtype to inform surgical decision-making. The findings are expected to provide insight into the reliability of current imaging strategies for predicting residual disease and support evidence-based surgical planning in the neoadjuvant setting.

MATERIALS AND METHODS

Study design

This retrospective observational study was conducted at Siriraj Hospital and Siriraj Piyamaharajkarun Hospital in Bangkok, Thailand, with ethical approval from the Siriraj Institutional Review Board.

Patient selection

Female patients with histologically confirmed breast cancer who received NAST followed by surgery between January 2016 and December 2024 were reviewed.

Inclusion criteria:

1. Age ≥18 years
2. Receipt of NAST (chemotherapy, targeted therapy, or immunotherapy)
3. Availability of preoperative MRI and US within 3–6 weeks before surgery
4. Complete histopathological report from surgery

Exclusion criteria:

1. MRI performed at outside institutions
2. Incomplete imaging or pathology records

Out of 196 breast cancer patients reviewed: 156 did not receive NAST, 8 lacked post-NAST MRI, 6 lacked post-NAST ultrasound for comparison, and 2 had incomplete clinical or imaging data, as shown in Fig 1. Ultimately, 24 patients were included in the study.

Imaging technique and imaging analysis

Imaging protocols were standardized. Breast MRI included axial T1-weighted (T1W) and sagittal T2-weighted (T2W) fat-suppressed sequences, diffusion-weighted imaging (DWI), and post-contrast dynamic series using

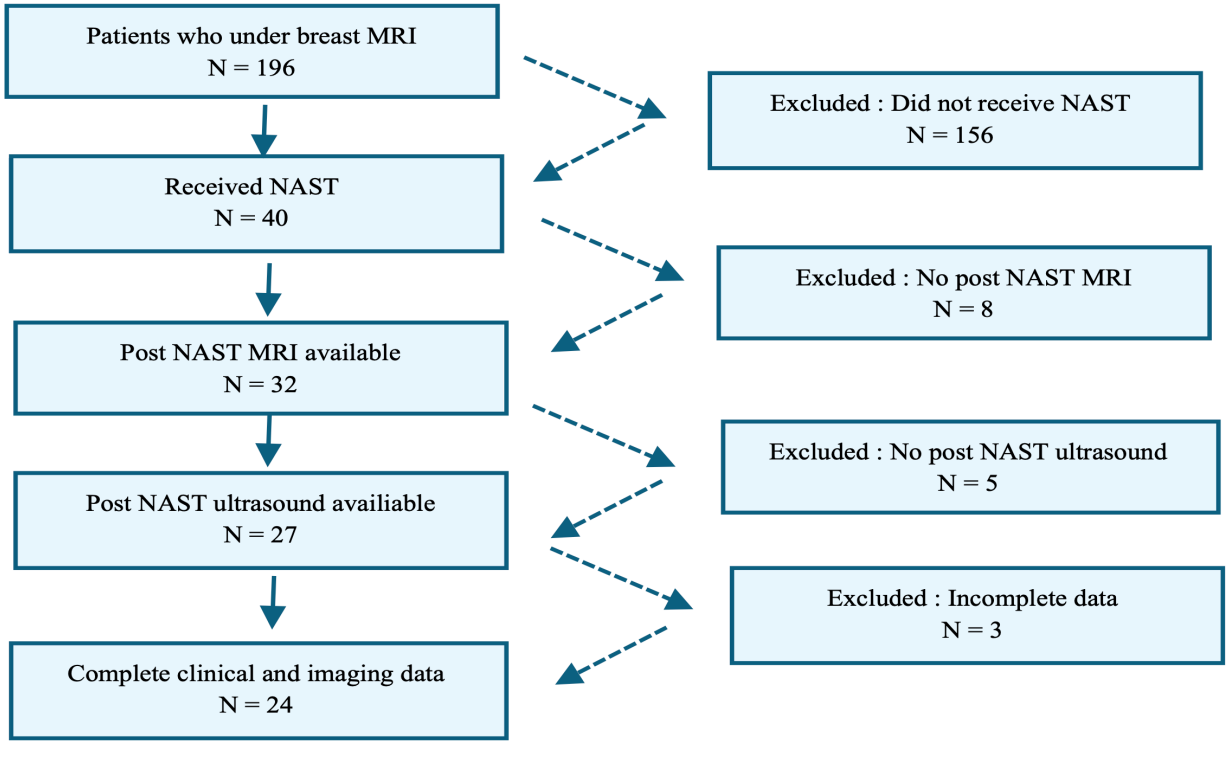


Fig 1. The chart illustrates the patient recruitment flow in this study.

gadolinium. Only measurable mass lesions were used for primary tumor size estimation; NME was recorded but excluded from initial measurements. Ultrasound was performed using high-resolution linear-array transducers and interpreted by board-certified radiologists.

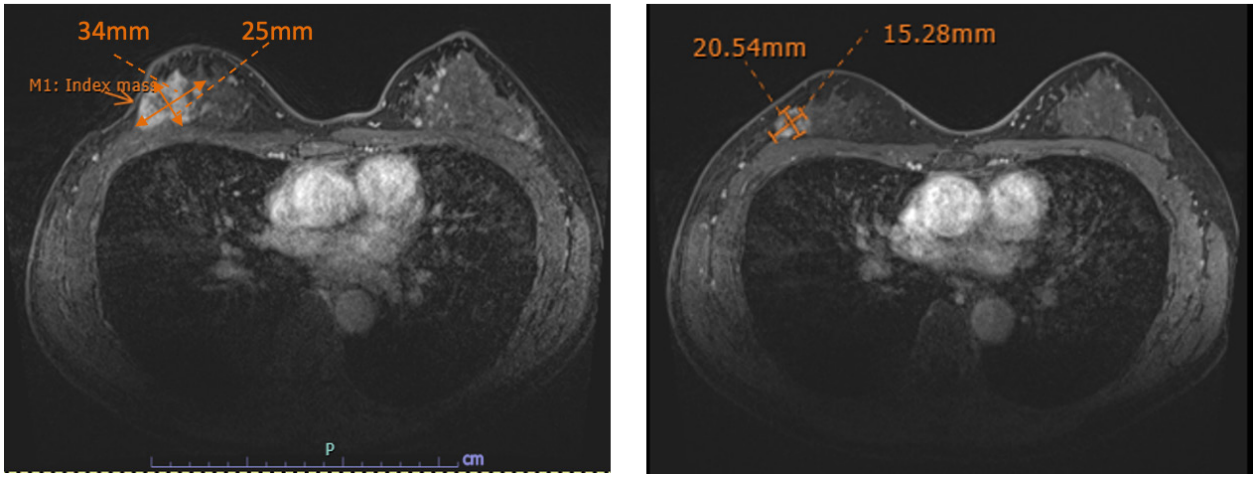
To ensure reliability and minimize interpretive bias, two board-certified breast radiologists independently reviewed the MRI scans, blinded to the surgical pathology results. In cases demonstrating non-mass enhancement (NME), the maximal linear extent was measured in millimeters using dynamic contrast-enhanced sequences. Inter-observer agreement demonstrated substantial reliability, with an intraclass correlation coefficient (ICC) of 0.67. According to standard interpretation criteria, ICC values between 0.61 and 0.80 are indicative of substantial agreement.

With regard to tumor response patterns following neoadjuvant systemic therapy (NAST), two distinct types were identified: concentric shrinkage as demonstrated in Fig 2A and 2B and scattered shrinkage, as shown in Fig 3A and 3B. These patterns were documented and analyzed in relation to the molecular subtypes of breast cancer to assess potential correlations.

Data collected included age, tumor histology and subtype, imaging findings, type of surgery, and pathologic tumor size. Molecular subtypes were categorized as HER2-enriched, TNBC, or luminal B, based on immunohistochemistry and DISH results.

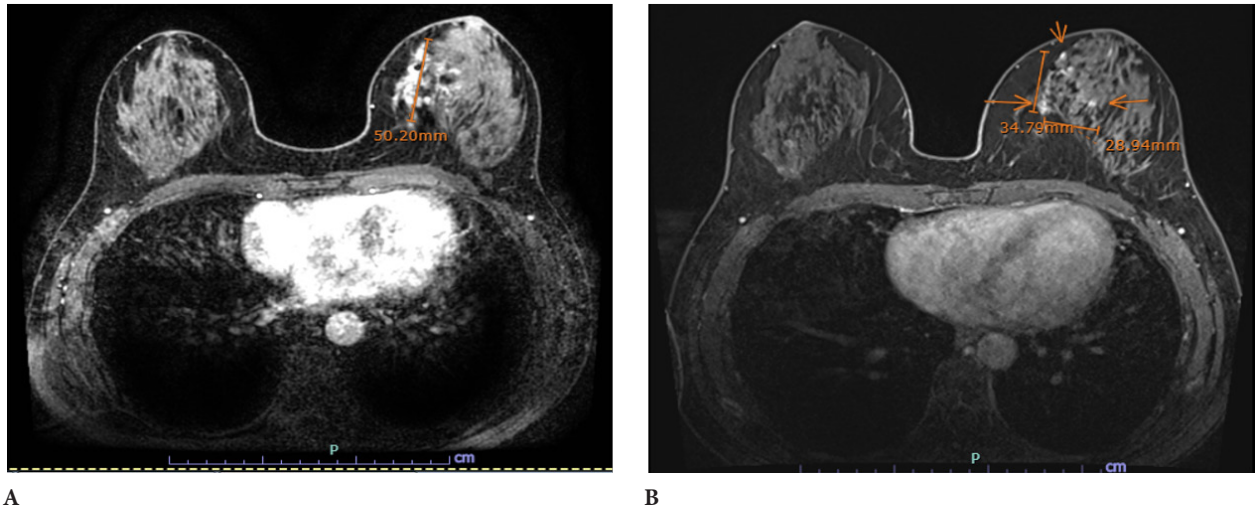
Statistical analysis

Descriptive statistics were used for mean, standard deviation (SD), median, minimum, maximum, and range.



A B

Fig 2. Concentric shrinkage response on MRI. Fig 2A and 2B demonstrate MRI at initial diagnosis and after completion of NAST, respectively.



A B

Fig 3. Scattered shrinkage response on MRI. Fig 3A and 3B depict MRI scans at initial diagnosis and following completion of NAST, respectively.

Crosstabulation analysis was conducted to evaluate categorical agreement between imaging-based tumor size categories and was expressed as the proportion (%) of correctly classified cases. Bland-Altman plots were used to assess agreement between imaging and pathology. Statistical analyses were performed using SPSS version 29.

RESULTS

A total of 24 patients were initially identified, as shown in Table 1. All patients received neoadjuvant systemic treatment based on their cancer subtypes prior to surgery. Regarding surgical treatment, 62.5% (n = 15) of patients underwent wide excision, while 37.5% (n = 9) underwent mastectomy, including modified radical mastectomy (MRM), nipple-sparing mastectomy (NSM), and total mastectomy (TM). Non-mass enhancement (NME) on preoperative MRI was observed in 37.5% (n = 9) of patients, while the remaining 62.5% (n = 15) showed no evidence of NME. Following neoadjuvant treatment, the predominant tumor shrinkage pattern observed on MRI was concentric mass shrinkage, present in 83.3% (n = 20) of patients. In contrast, a scattered or NME shrinkage pattern was identified in 16.7% (n = 4). The tumor dimensions reported on MRI, ultrasound (US), and pathology were based on the longest diameter of the lesion.

Table 2 presents the distribution of tumor shrinkage patterns according to molecular subtype. Concentric shrinkage was observed in the majority of cases (83.3%), while scattered shrinkage was identified in 16.7%. Among patients with triple-negative breast cancer (TNBC), 72.7% exhibited a concentric shrinkage pattern, whereas scattered shrinkage was observed in 3 of 11 cases (27.3%). In the luminal B HER2-negative group, 83.3% demonstrated concentric shrinkage. Notably, all cases in the luminal B HER2-positive and HER2-overexpressing subtypes exhibited concentric shrinkage exclusively. Although descriptive trends suggest that HER2-driven tumors and luminal B subtypes are more likely to exhibit concentric shrinkage patterns, statistical analysis did not reveal a significant association between molecular subtype and shrinkage pattern (p = 0.646), which may, in part, be attributed to the limited sample size.

To evaluate clinical agreement between imaging modalities and pathological tumor size, a predefined threshold of ±10 mm was applied. MRI demonstrated high overall agreement with pathological measurements, with 91.7% of cases falling within the ±10 mm threshold. Only two patients (8.3%) exceeded this threshold, both of whom had invasive lobular carcinoma (ILC), a subtype known for its diffuse growth and less distinct imaging characteristics. In contrast, US measurements deviated by more than ±10 mm in 7 patients (29.1%), indicating

TABLE 1. Demographic data for all 24 patients recruited in the study—including breast cancer subtype, type of breast surgery, presence of NME on pre-NAST MRI, and shrinkage pattern on post-NAST MRI prior to surgery.

Characteristic	N = 24 (%)
Subtype	
Triple-negative (TNBC)	11 (45.8%)
Luminal B HER2 negative	6 (25%)
Luminal B HER2 positive	4 (16.7%)
HER2 overexpression	3 (12.5%)
Surgery Type	
Wide excision (WE)	15 (62.3%)
Mastectomy (MRM, NSM, TM)	9 (37.5%)
Presence of NME on MRI	
Yes	9 (37.5%)
No	15 (62.5%)
Shrinkage Pattern in MRI	
Concentric	20 (83.3%)
Scattered	4 (16.7%)

Abbreviations: TNBC – triple-negative breast cancer, WE – wide excision, MRM – modified radical mastectomy, NSM – nipple-sparing mastectomy, TM – total mastectomy, NME – non-mass enhancement

TABLE 2. Distribution of tumor shrinkage patterns by molecular subtype in breast cancer patients following NAST. The table summarizes the frequency of concentric and scattered shrinkage patterns across molecular subtypes. While concentric shrinkage was predominant overall, variation was observed among subtypes.

Subtype	Concentric shrinkage	Scattered shrinkage
Triple-negative	8	3
Luminal B HER2 negative	5	1
Luminal B HER2 positive	4	0
HER2 overexpression	3	0

a greater discrepancy compared to MRI and a higher likelihood of both underestimation and overestimation compared to pathology. Table 3 summarizes the mean, median, and standard deviation of tumor sizes as measured by MRI, US, and pathological examination.

These results suggest that MRI provides a more accurate and reliable estimation of residual tumor size following neoadjuvant treatment, whereas US may be more prone to underestimation or overestimation, particularly in tumors with diffuse growth patterns, such as invasive lobular carcinoma.

According to the Bland–Altman plots presented in Fig 4, MRI and US demonstrated differing levels of agreement with pathological tumor size following neoadjuvant treatment. For MRI (Fig 4.1), the mean difference between pathological and MRI measurements was +5.5 mm, indicating a slight tendency for MRI to overestimate tumor size. The limits of agreement ranged from –23.5 mm to +34.5 mm, reflecting moderate variability. Most measurements clustered near the mean, with only two data points falling outside the 95% confidence limits—both corresponding to cases of invasive lobular carcinoma (ILC), a subtype characterized by diffuse growth and ill-defined imaging features. The 95% confidence interval (CI) for the mean difference was –0.7 to 11.7 mm.

In contrast, the US Bland–Altman plot (Fig 4.2) revealed greater variability. Although the mean difference was slightly lower at +2.6 mm, the limits of agreement were considerably wider (–32.8 mm to +38.0 mm), indicating lower consistency and weaker agreement with pathological measurements. The 95% CI for the mean difference was –5.0 to 10.2 mm.

The difference in agreement between MRI and US in estimating residual tumor size was not statistically significant at the conventional $\alpha = 0.05$ level; however, a trend toward significance was observed, with a two-sided

TABLE 3. Comparison of tumor size measurements by imaging modality and pathology.
Mean, median, and standard deviation of lesion size as determined by MRI, US, and pathological examination. The proportion of cases exceeding a ±10 mm discrepancy from pathological tumor size is also reported as the percentages.

Modality	Mean Tumor Size (mm)	Standard Deviation (SD)	Accuracy within 10 mm
MRI	5.4 (0-20.5)	6.34	91.67%
Ultrasound	8.3 (0-25.4)	8.1	70.83%
Pathological Report	10.9 (0-25.0)	16.1	

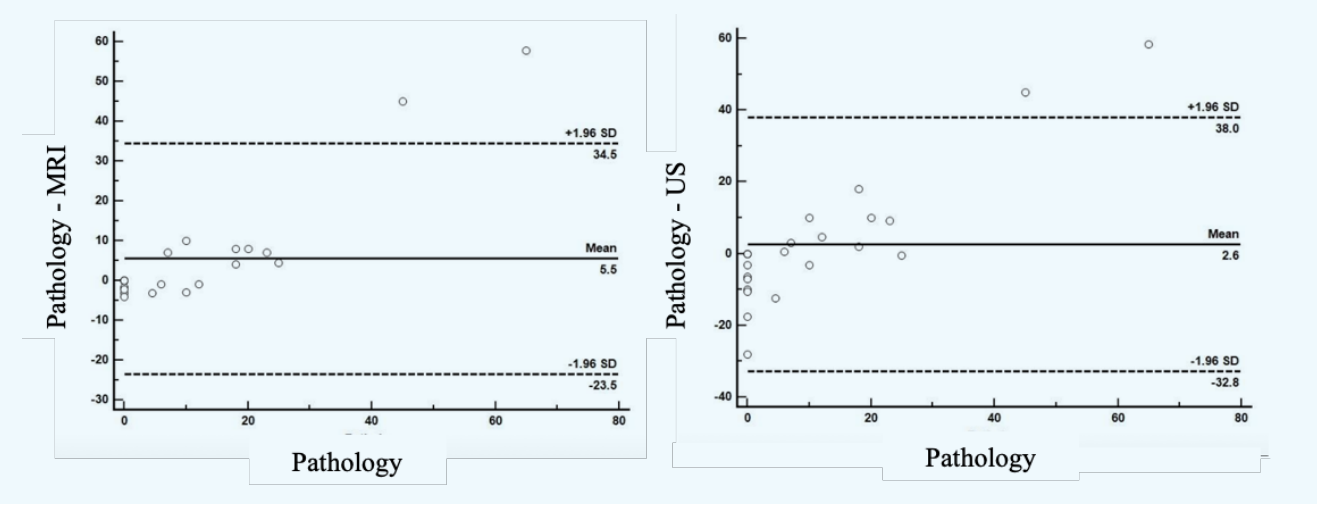


Fig 4.1 Fig 4.2

Fig 4. Bland–Altman analysis of agreement between imaging modalities and pathological tumor size following NAST in all 24 patients. Fig 4.1: Bland–Altman plot comparing MRI measurements with pathological tumor size. Fig 4.2: Bland–Altman plot comparing US measurements with pathological tumor size.

p-value of 0.081 for the comparison between MRI and pathological measurements. In contrast, the US–pathology comparison yielded a non-significant p-value of 0.489.

Notably, when the two cases of invasive lobular carcinoma (ILC) were excluded from the analysis, MRI demonstrated minimal bias (mean difference = 1.3 mm) with narrow limits of agreement (–7.0 mm to +9.6 mm), indicating good concordance with pathological measurements. The 95% confidence interval (CI) for the mean difference was –0.53 to 3.21 mm.

Conversely, ultrasound (US) exhibited greater bias (mean difference = –1.9 mm) and wider limits of agreement (–21.7 mm to +17.9 mm), reflecting increased variability and reduced agreement with pathology, as illustrated in Figure 5. The 95% confidence interval (CI) for the mean difference was –6.3 to 2.5 mm.

Subgroup analysis by tumor size category

To further evaluate diagnostic performance according to tumor size, patients were stratified into two groups based on pathological tumor size: < 10 mm. and ≥ 10 mm.

Among the 14 patients with tumors < 10 mm. on pathology, MRI correctly classified all cases, yielding a concordance rate of 100.0%. In the ≥ 10 mm. group (n = 10), MRI accurately identified seven patients (70.0%),

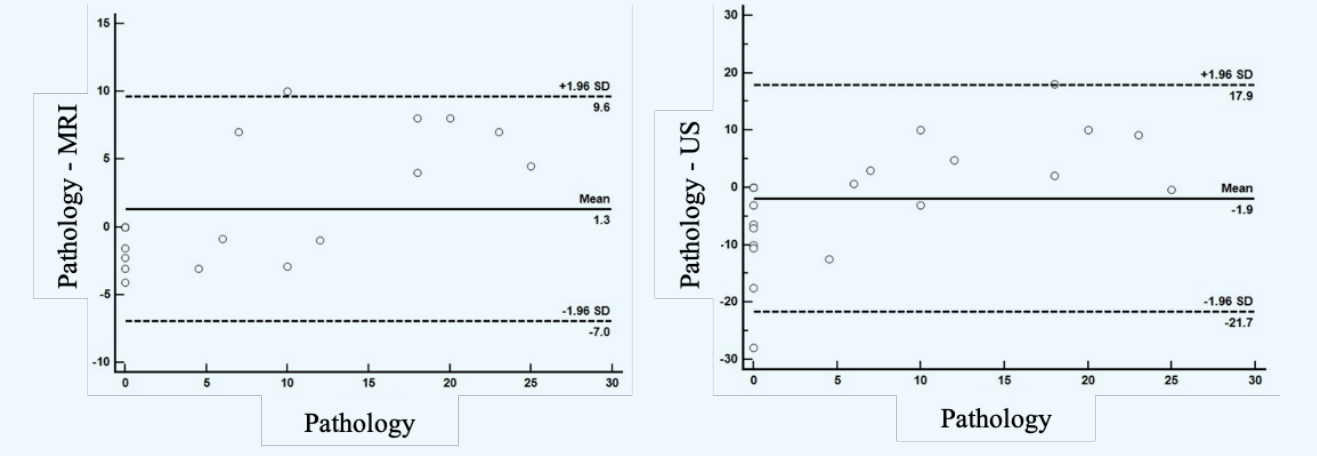


Fig 5.1 Fig 5.2

Fig 5. Bland–Altman analysis of agreement between imaging modalities and pathological tumor size after exclusion of invasive lobular carcinoma (ILC) cases. Fig 5.1: Bland–Altman plot comparing MRI with pathological tumor size. Fig 5.2: Bland–Altman plot comparing US with pathology. The plots demonstrate that MRI exhibits closer agreement with pathology, with lower bias and narrower limits of agreement compared to US.

with three cases underestimated as < 10 mm. (30.0%). In contrast, ultrasound showed lower concordance with pathological findings. Among patients with tumors < 10 mm., nine of 14 cases (64.3%) were correctly classified, while five cases were misclassified. In the ≥ 10 mm. group, five of ten cases (50.0%) were correctly identified. These findings correspond to classification accuracies of 64.3% for tumors < 10 mm and 50.0% for tumors ≥ 10 mm using ultrasound.

The comparative analysis of MRI and US in estimating residual tumor burden following NAST demonstrated superior consistency and accuracy of MRI in correlation with final pathological measurements. In the full cohort (N = 24), the correlation between MRI and pathology approached statistical significance ($r = 0.401$, $p = 0.052$), with a mean paired difference of 5.51 mm ($p = 0.081$) and a moderate effect size (Cohen's $d = 0.372$). In contrast, US demonstrated negligible correlation with pathological tumor size ($r = 0.005$, $p = 0.983$) and exhibited greater variability in size estimation.

Of particular interest, when two cases of invasive lobular carcinoma were excluded from the analysis (N = 22), the correlation between MRI and pathology improved substantially ($r = 0.882$, $p < 0.001$). However, the corresponding mean difference and effect size were reduced and did not reach statistical significance (mean difference $p = 0.152$, Cohen's $d = 0.317$). These findings suggest that specific tumor subtypes—particularly ILC, which is characterized by a diffuse growth pattern and a tendency to present as non-mass enhancement (NME) on MRI—may limit the accuracy and reliability of MRI-based tumor size estimation.

The stronger correlation observed in the complete dataset may better reflect the heterogeneity encountered in routine clinical practice. Therefore, while MRI remains a valuable modality for preoperative assessment, its interpretation should be contextualized with respect to tumor biology and imaging phenotype, particularly in histologic subtypes such as ILC, where diffuse growth patterns may lead to underestimation. Overall, MRI consistently demonstrated superior agreement with pathological tumor size compared to US, regardless of tumor dimension, supporting its greater accuracy in preoperative tumor evaluation following neoadjuvant therapy.

DISCUSSION

This study demonstrates the superior accuracy of breast magnetic resonance imaging (MRI) compared to ultrasound (US) in assessing residual tumor size following neoadjuvant systemic therapy (NAST) in patients with breast cancer. Notably, MRI maintained measurement accuracy within ±10 mm of pathological size in 91.7% of cases—a clinically meaningful threshold in surgical planning, particularly for ensuring adequate oncologic margins while enabling breast-conserving approaches. In contrast, US overestimated tumor size by more than 10 mm in seven cases and underestimated it in one case. These findings highlight the greater consistency and precision of MRI in the preoperative evaluation of residual disease.

Our data further indicate that MRI provided narrower limits of agreement and more accurate tumor size classification than US. This advantage was especially evident in lesions smaller than 10 mm., where precise measurements are critical for evaluating breast-conserving surgery (BCS) feasibility and ensuring appropriate margin clearance. Importantly, in cases of ILC, conventional MRI techniques focusing solely on mass-forming lesions tended to underestimate disease extent. Incorporating non-mass enhancement (NME) into radiologic assessment substantially improved correlation with pathological findings. This aligns with prior reports suggesting that the diffuse infiltration pattern and low cellularity of ILC require a tailored imaging approach that considers both mass and NME characteristics. Future imaging protocols should thus integrate comprehensive assessment strategies, particularly for lobular and low-grade tumors.

Accurate preoperative imaging is crucial not only for optimizing surgical strategy but also for reducing reoperation rates and minimizing the risk of local recurrence or distant metastasis. Although multiple imaging modalities are used to assess residual disease post-NAST, no single technique has yet been established as the gold standard. First-line options such as mammography and US are limited by factors including breast density, resolution, and operator dependency—challenges that are further compounded post-NAST due to altered tumor morphology. While lesions ≥ 7 mm are more reliably detected, overall accuracy remains moderate, typically ranging from 60% to 80%.[9]

Automated breast ultrasound (ABUS) provides a standardized, operator-independent approach with multiplanar imaging capabilities. Reported diagnostic metrics for ABUS include a sensitivity of 22.2%, specificity of 95.2%, positive predictive value (PPV) of 50.0%, and negative predictive value (NPV) of 85.1%.[10] Digital breast tomosynthesis (DBT), which addresses the tissue overlap limitations of 2D mammography, improves delineation of tumor margins. For prediction of pathological complete response (pCR), DBT has shown a sensitivity of 44.7%, specificity of 97.6%, PPV of 85.7%, and NPV of 93.2%.[11-14]

Contrast-enhanced mammography (CEM), which combines dual-energy acquisition with iodinated contrast, serves as a valuable adjunct when standard mammography is inconclusive, with reported sensitivity, specificity, and accuracy of 81%, 83%, and 82%, respectively.

MRI has increasingly been adopted for preoperative assessment due to its high sensitivity and superior soft-tissue contrast. One study reported MRI sensitivity, specificity, and accuracy for residual disease detection at 100%, 86%, and 90%, respectively. In direct comparison, Bernardi et al. found MRI significantly more sensitive than CEM in detecting pCR.[15] A systematic review reported a median MRI sensitivity of 42%, specificity of 89%, PPV of 64%, and NPV of 87%.[16] In a meta-analysis of 25 studies, Yuan et al. reported pooled MRI sensitivity and specificity for predicting pCR of 63% (95% CI: 56–70%) and 91% (95% CI: 89–92%), respectively.[17] However, despite its strengths, MRI remains susceptible to false positives, which may lead to overtreatment or unnecessary mastectomy.

International guidelines support the use of MRI in this context. The European Society of Breast Cancer Specialists (EUSOMA) recommends pre-NAST MRI for patients considered for BCS, to better evaluate tumor extent and breast anatomy. Likewise, the American College of Radiology (ACR) recognizes MRI as the most specific modality for assessing residual disease and post-treatment breast changes. This is particularly relevant in Asian populations, where dense breast tissue poses a challenge for mammographic interpretation.[18] MRI has been shown to outperform both mammography and US in lesion detection,[19-23] and uniquely identifies multifocal or multicentric disease, non-mass lesions, contralateral synchronous tumors, and tumor shrinkage patterns—all of which are critical in guiding surgical decisions.

Although MRI demonstrates greater accuracy in estimating tumor extent compared to US, US remains clinically valuable in routine practice. Its advantages include broader accessibility, lower cost, and the capability for real-time, dynamic assessment at the point of care. These features make US particularly useful in resource-limited settings or among patients who are not suitable candidates for MRI. In addition, US provides complementary information—such as lesion vascularity and tissue elasticity—that can aid in the characterization of indeterminate findings.

From a surgical standpoint, inaccurate estimation of tumor extent on imaging can have direct implications for operative planning. Overestimation may result in unnecessarily wide excision or mastectomy, whereas underestimation increases the risk of positive margins and subsequent reoperation. In a study by Thiravit et al.[24], MRI maintained high diagnostic accuracy across different levels of background parenchymal enhancement (BPE), with accuracy rates of 84.4% in minimal-to-mild BPE and 73.3% in moderate-to-marked BPE, with no statistically significant difference observed ($p = 0.35$). These findings suggest that preoperative MRI can accurately evaluate tumor extent in breast cancer, and that moderate-to-marked background enhancement does not significantly impact its performance.

Several limitations of this study must be acknowledged. Its retrospective nature limits causal inference and introduces potential selection bias. The sample size was modest, restricting the power of subgroup analyses, particularly among luminal and lobular subtypes. Moreover, interobserver variability in the interpretation of NME was not formally evaluated, although a second blinded review by an experienced radiologist confirmed consistency with initial reports.

Future prospective studies with larger, subtype-stratified cohorts are needed to validate these findings. Standardized radiologic response criteria that incorporate both mass and NME characteristics may enhance consistency across institutions. Furthermore, integrating advanced functional MRI techniques—such as diffusion-weighted imaging (DWI) and dynamic contrast-enhanced (DCE) sequences—could refine evaluation of post-NAST residual disease, particularly in non-pCR cases.

In summary, our findings affirm the diagnostic value of MRI in evaluating post-NAST residual disease and emphasize the need to integrate tumor biology into radiologic interpretation. With further validation, preoperative breast MRI should be established as a key component of surgical planning for selected breast cancer patients, particularly when conventional imaging modalities are likely to underperform.

CONCLUSION

This study demonstrates that breast MRI provides superior accuracy compared to US in evaluating residual tumor burden following neoadjuvant systemic therapy, particularly in HER2-positive, triple-negative, and subcentimeter tumors. MRI enhances surgical planning by improving preoperative tumor size estimation and reducing the likelihood of positive surgical margins. In the context of breast-conserving surgery, accurate imaging is critical in determining surgical eligibility and supports treatment decisions that are both oncologically sound and aligned with patient preferences.

The findings also highlight important considerations in specific tumor subtypes. Invasive lobular carcinoma

and certain luminal tumors often present with non-mass enhancement that may not be captured through conventional measurement criteria. Integrating these imaging patterns into preoperative assessment may prevent underestimation of disease extent and reduce the likelihood of inadequate resections.

Given these clinical implications, use of preoperative MRI should be considered in patients undergoing neoadjuvant therapy, especially when imaging findings will critically inform surgical decision-making. Incorporating tumor biology and response patterns into radiologic interpretation is not only diagnostically advantageous but also essential in tailoring surgery to the individual patient.

However, several limitations must be acknowledged, including the retrospective study design and relatively small sample size. Therefore, while the findings support the clinical utility of MRI in this context, prospective studies are warranted to validate these results before routine implementation in all clinical settings.

Data Availability Statement

The datasets generated and/or analyzed during the current study include patient information and medical imaging, which are subject to ethical and legal restrictions. As such, these data are not publicly available. De-identified data may be made available from the corresponding author upon reasonable request and with approval from the Siriraj Institutional Review Board.

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DECLARATIONS

Grants and Funding Information

None.

Conflict of Interest

None.

Registration Number of Clinical Trial

No due to retrospective observational study.

Author Contributions

Conceptualization and methodology, A.I., P.K., S.C., and W.I. ; Investigation, A.I., S.T., V.S., P.R., W.I. ; Formal analysis, A.I. and W.I. ; Visualization and writing – original draft, A.I. ; Writing – review and editing, W.I. ; Funding acquisition, A.I. and W.I.; Supervision, W.I. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

None.

REFERENCES

1. ทะเบียนมะเร็งระดับโรงพยาบาล พ.ศ. 2564 สถาบันมะเร็งแห่งชาติกรมการแพทย์กระทรวงสาธารณสุข, www.nci.go.th/e_book/hosbased_2564/index.html
2. Cortazar P, Zhang L, Untch M, Mehta K, Costantino JP, Wolmark N, et al. Pathological complete response and long term clinical benefit in breast cancer: the CTNeoBC pooled analysis. Lancet. 2014;384:164-72.
3. Zheng C-H, Xu K, Shan W-P, Zhang Y-K, Su Z-D, Gao X-J, et al. Meta-Analysis of Shrinkage Mode After Neoadjuvant Chemotherapy for Breast Cancers: Association With Hormonal Receptor. Front Oncol. 2022;11:617167.
4. Negarao EMS, Souza JA, Marques EF. Breast cancer phenotype influences MRI response evaluation after neoadjuvant chemotherapy. Eur J Radiol. 2019;120:108701.
5. Price ER, Wong J, Mukhtar R, Hylton N, Esserman LJ. How to use magnetic resonance imaging following neoadjuvant chemotherapy in locally advanced breast cancer. World J Clin Cases. 2015;3(7):607-13.
6. Boughey JC, McCall LM, Ballman KV, Mittendorf EA, Ahrendt GM, Wilke LG, et al. Tumor Biology Correlates With Rates of Breast-Conserving Surgery and Pathologic Complete Response After Neoadjuvant Chemotherapy for Breast Cancer: Findings From the ACOSOG Z1071 (Alliance) Prospective Multicenter Clinical Trial. Ann Surg. 2014; 260(4):608–16.
7. JEON-HOR CHEN. Impact of Factors Affecting the Residual Tumor Size Diagnosed by MRI Following Neoadjuvant Chemotherapy in Comparison to Pathology. J Surg Oncol. 2014;109(2):158-67.
8. Kim J, Han B, Ko E, Ko E, Choi J, Park K. Prediction of pathologic complete response on MRI in patients with breast cancer receiving neoadjuvant chemotherapy according to molecular subtypes. Eur Radiol. 2022;32(6):4056-66.
9. Croshaw R, Shapiro-Wright H, Svensson E, Erb K, Julian T. Accuracy of clinical examination, digital mammogram, ultrasound, and MRI in determining postneoadjuvant pathologic tumor response in operable breast cancer patients. Ann Surg Oncol. 2011;18:3160-3.
10. Jiyoon Park, Eun Young Chae, Jo Hee Cha, Hee Jung Shin, Woo Jung Choi, Young-Wook Choi, et al. Comparison of mammography, digital breast tomosynthesis, automated T breast ultrasound, magnetic resonance imaging in evaluation of residual tumor after neoadjuvant chemotherapy. Eur J Radiol. 2018;108:261–8.
11. Poplack SP, Tosteson TD, Kogel CA, Nagy HM. Digital breast tomosynthesis: initial experience in 98 women with abnormal digital screening mammography. AJR Am J Roentgenol. 2007;189(3): 616–23.
12. Fornvik D, Zackrisson S, Ljungberg O, Svahn T, Timberg P, Tingberg A, Andersson I. Breast tomosynthesis: accuracy of tumor measurement compared with digital mammography and ultrasonography. Acta Radiol. 2010;51(3):240–7.

13. Hakim CM, Chough DM, Ganott MA, Sumkin JH, Zuley ML, Gur D. Digital breast tomosynthesis in the diagnostic environment: a subjective side-by-side review. AJR Am. J Roentgenol. 2010; 195:W172–6.
14. Park JM, Franken Jr. EA, Garg M, Fajardo LL, Niklason LT. Breast tomosynthesis: present considerations and future applications. Radiographics. 2007;27 Suppl 1:S231–S40.
15. Bernardi D, Vatteroni G, Acquaviva A, Valentini M, Sabatino V, Bolengo I, et al. Contrast-Enhanced Mammography Versus MRI in the Evaluation of Neoadjuvant Therapy Response in Patients With Breast Cancer: A Prospective Study. AJR Am J Roentgenol. 2022;219(6):884–94.
16. Lobbes MBI, Previous R, Smidt M, Tjan-Heijnen VCG, van Goethem M, Schipper R, et al. The role of magnetic resonance imaging in assessing residual disease and pathologic complete response in breast cancer patients receiving neoadjuvant chemotherapy: a systematic review. Insights Imaging. 2013; 4(2):163–75.
17. Yuan Y, Chen X-S, Liu S-Y, Shen K-W. Accuracy of MRI in prediction of pathologic complete remission in breast cancer after preoperative therapy: a meta-analysis. AJR Am J Roentgenol. 2010;195(1):260– 8.
18. Marinovich ML, Houssami N, Macaskill P, Sardanelli F, Irwig L, Mamounas EP, et al. Meta-analysis of Magnetic Resonance Imaging in Detecting Residual Breast Cancer After Neoadjuvant Therapy. J Natl Cancer Inst. 2013;105:321–33.
19. França LKL, Bitencourt AGV, Paiva HLS, Silva CB, Pereira NP, Paludo J, et al. Role of magnetic resonance imaging in the planning of breast cancer treatment strategies: comparison with conventional imaging techniques. Radiol Bras. 2017;50(2):76–81.
20. França LKL, Bitencourt AGV, Osório VAB, Graziano L, Guatelli CS, Souza JA, et al. Tumor size assessment of invasive breast cancers: which pathological features affect MRI-pathology agreement. Applied Cancer Research. 2018;38:2.
21. Ko ES, Han BK, Kim RB, Ko EY, Shin JH, Hahn SY, et al. Analysis of Factors That Influence the Accuracy of Magnetic Resonance Imaging for Predicting Response after Neoadjuvant Chemotherapy in Locally Advanced Breast Cancer. Ann Surg Oncol. 2013; 20:2562–8.
22. Bahri S, Chen JH, Mehta RS, Carpenter PM, Nie K, Kwon S, et al. Residual Breast Cancer Diagnosed by MRI in Patients Receiving Neoadjuvant Chemotherapy with and Without Bevacizumab. Ann Surg Oncol. 2009;16:1619–28.
23. Kim HJ, Im YH, Han BK, Choi N, Lee J, Kim JH, et al. Accuracy of MRI for Estimating Residual Tumor Size after Neoadjuvant Chemotherapy in Locally Advanced Breast Cancer: Relation to Response Patterns on MRI. Acta Oncol Stockh Swed. 2007;46: 996–1003.
24. Thiravit S. The Background Parenchymal Enhancement in Preoperative Breast MRI: The Effect on Tumor Extent Evaluation. Siriraj Med J. 2017;69(5):290-6.

Structured Multidisciplinary Approach to Ruptured Abdominal Aortic Aneurysm: Impact on Mortality and Complications in a 13-Year Cohort

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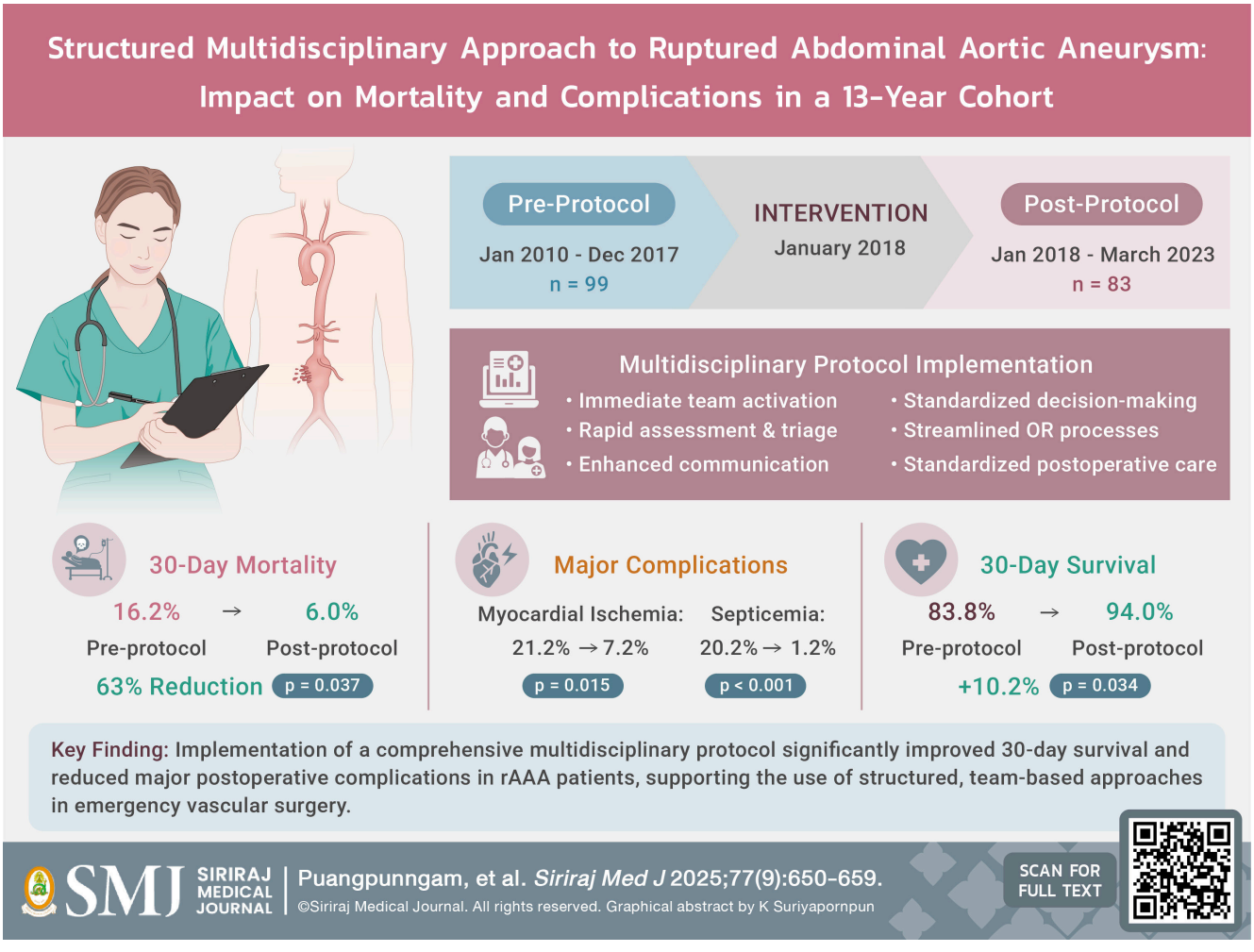

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ABSTRACT

Objective: To evaluate the impact of a comprehensive multidisciplinary protocol on 30-day survival in ruptured abdominal aortic aneurysm (rAAA) patients and to identify factors influencing outcomes.

Materials and Methods: We conducted a retrospective study comparing outcomes before and after implementation of a multidisciplinary protocol for rAAA management at Siriraj Hospital. The study included 182 patients (pre-protocol: n=99, January 2010-December 2017; post-protocol: n=83, January 2018-March 2023). Primary outcome was 30-day overall survival, with secondary outcomes including factors influencing survival, need for aortic balloon occlusion, operative parameters, length of stay, and complications.

Results: The 30-day mortality rate significantly decreased from 16.2% pre-protocol to 6.0% post-protocol (p=0.037). Kaplan-Meier analysis showed improved 30-day survival in the post-protocol group (94.0% vs 83.8%, p=0.034). However, while protocol implementation was associated with a non-significant reduction in mortality hazard (adjusted HR 0.509, 95% CI 0.175-1.478, p=0.213), multivariable analysis identified cardiac arrest (aHR 8.180, p<0.001) and unfit patient status (aHR 6.420, p=0.003) as independent predictors of mortality. The post-protocol group had significantly reduced myocardial ischemia (7.2% vs 21.2%, p=0.015) and septicemia (1.2% vs 20.2%, p<0.001), with no significant differences in operative parameters or length of stay.

Conclusion: Implementation of a multidisciplinary protocol for rAAA management was associated with improved 30-day survival and reduced postoperative complications, supporting the use of structured protocols in rAAA management.

Keywords: Ruptured AAA; protocol; multidisciplinary team; outcomes; perioperative mortality (Siriraj Med J 2025; 77: 650-659)

INTRODUCTION

Ruptured abdominal aortic aneurysm (rAAA) represents one of the most critical emergencies in vascular surgery, requiring immediate medical attention and surgical intervention.[1] It remains a life-threatening condition associated with high mortality rates, with recent studies reporting mortality rates ranging from 30% to 50%.[2,3] Despite advancements in surgical techniques and perioperative care, the management of rAAA continues to pose significant challenges to healthcare providers. The time-sensitive nature of the condition, coupled with the complex interplay of factors affecting patient outcomes, necessitates a coordinated and efficient approach to care.[4]

In recent years, there has been growing interest in the implementation of standardized protocols and multidisciplinary approaches to improve outcomes in rAAA patients.[5,6] These protocols aim to streamline the diagnostic and treatment processes, optimize resource utilization, and enhance communication among various healthcare team members involved in patient care.

Our institution, Siriraj Hospital in Bangkok, Thailand, implemented a comprehensive multidisciplinary protocol for rAAA management in January 2018. This study aims to evaluate the impact of this protocol on 30-day overall survival in rAAA patients and identify factors influencing outcomes. By comparing pre- and post-protocol periods, we seek to provide valuable insights into the effectiveness of structured approaches in managing this critical condition.[7] However, our outcomes could have been influenced by several confounding factors that evolved over time, including advancements in device technologies, improved ICU care, and increased surgeon experience.

The findings of this study have the potential to inform clinical practice and contribute to the ongoing efforts to reduce mortality and morbidity associated with rAAA.[8] Moreover, by identifying predictors of mortality, we aim to enhance risk stratification and guide decision-making in the acute management of rAAA patients.[9]

MATERIALS AND METHODS

Study design and population

We conducted a retrospective study at Siriraj Hospital, a tertiary referral center in Bangkok, Thailand, comparing outcomes before and after implementation of a multidisciplinary protocol for rAAA management. The study included all patients treated for rAAA between January 2010 and March 2023, divided into pre-protocol (January 2010-December 2017) and post-protocol (January 2018-March 2023) groups.

Inclusion and exclusion criteria

The study included patients with radiologically or intraoperatively confirmed rAAA who were aged ≥ 18

years, who underwent either endovascular aortic aneurysm repair (EVAR) or open surgical repair (OSR). We excluded patients who died before surgical intervention, those with thoracoabdominal aortic aneurysms, and individuals with previous aortic surgery. The Siriraj Institutional Review Board (SIRB) granted ethical approval for this research investigation under certificate of approval number Si 279/2022.

Multidisciplinary protocol

In January 2018, we implemented a comprehensive multidisciplinary protocol with several key components (Fig 1). The protocol mandated immediate activation of a multidisciplinary team upon suspicion of rAAA, followed by rapid assessment and triage based on hemodynamic stability. For stable patients, we conducted expedited computed tomography angiography (CTA). The protocol established a standardized decision-making process for EVAR versus OSR and included preparation for potential aortic balloon occlusion in unstable patients. We activated a massive transfusion protocol when necessary and streamlined transfer processes for patients from referring hospitals. The protocol also ensured dedicated operating room availability for rAAA cases, preparedness for aortic balloon occlusion, standardized postoperative care, and regular team training and simulation exercises.

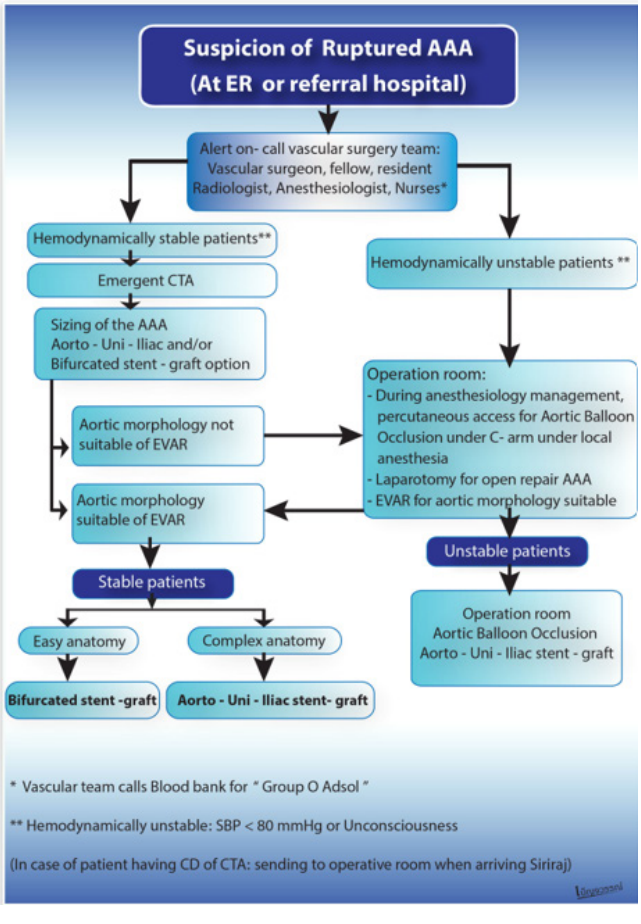

Fig 1. Multidisciplinary approach in managing ruptured abdominal aortic aneurysms.

Data collection

We collected data on patient demographics, comorbidities, preoperative condition, intraoperative details, and postoperative outcomes. Preoperative variables included age, gender, comorbidities (hypertension, diabetes, coronary artery disease, chronic obstructive pulmonary disease, and renal insufficiency), fit status, hemodynamic condition, and laboratory values. Impaired kidney function was characterized by serum creatinine exceeding 2 mg/dl. Patient classification as fit or unfit for intervention followed criteria established in the United Kingdom's EVAR 1 and 2 clinical trials, which evaluated patients based on cardiovascular, pulmonary, and kidney function parameters.[10] Intraoperative data encompassed the type of repair (EVAR or OSR), operative time, estimated blood loss, and use of aortic balloon occlusion. Postoperative variables included length of intensive care unit (ICU) and hospital stay, complications, and 30-day mortality.

Outcomes measurement

The primary outcome was 30-day overall survival. Secondary outcomes included factors influencing survival, need for aortic balloon occlusion, operative time, blood loss, length of hospital and ICU stay, and postoperative complications (including myocardial infarction, respiratory failure, renal failure requiring dialysis, bowel ischemia, and sepsis).

Statistical analysis

For statistical analysis, we employed various methods to compare the two groups and assess factors associated with 30-day survival. For categorical data, we used Pearson chi-square test, Yates' continuity correction, or Fisher's exact test as appropriate. Continuous data were analyzed using independent t-tests for normally distributed data and Mann-Whitney U tests for non-normally distributed data. We utilized the Kaplan-Meier method to generate survival curves and calculate survival rates, with differences between groups assessed using the log-rank test. To identify factors associated with 30-day survival, univariable logistic regression analyses were performed to identified potential predictors. Variables with p-values < 0.1 in the univariable analysis were subsequently entered into a multivariable logistic regression model using the backward stepwise selection method based on the likelihood ratio test (SPSS, PIN = 0.05, POUT = 0.10). Associations were quantified using both unadjusted and adjusted hazard

ratios (HR) with corresponding 95% confidence intervals (95% CI). All statistical tests were two-sided, and a p-value < 0.05 was considered statistically significant. Analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The study comprised 182 patients with ruptured abdominal aortic aneurysm (rAAA), who were divided into two cohorts based on treatment protocol implementation: a pre-protocol group (n=99; endovascular aortic repair [EVAR] n=72, open surgical repair [OSR] n=27) and a post-protocol group (n=83; EVAR n=44, OSR n=39). (Fig 2).

Demographic and clinical characteristics

The mean age of the study population was 72.3 ± 10.7 years, and 84.1% were male. Hypertension was the most common comorbidity (74.7%), followed by dyslipidemia (30.2%) and renal insufficiency (22.0%). The post-protocol group had a significantly higher proportion of patients with dyslipidemia (38.6% vs 23.2%, p=0.038) and a lower proportion of unfit patients (33.7% vs 55.6%, p=0.005) compared to the pre-protocol group. No significant differences were observed in other baseline characteristics between the two groups (Table 1).

Primary outcome

The implementation of the multidisciplinary protocol was associated with a significant reduction in 30-day mortality, decreasing from 16.2% in the pre-protocol group to 6.0% in the post-protocol group (p=0.037) (Fig 2). Kaplan-Meier analysis demonstrated improved 30-day overall survival in the post-protocol group (94.0% vs 83.8%, log-rank test p=0.034) (Fig 3).

Secondary outcomes

Multivariable Cox regression analysis revealed that protocol implementation was associated with a 49.1% reduction in the hazard of 30-day mortality (adjusted HR 0.509, 95% CI 0.175-1.478, p=0.213), although this did not reach statistical significance. Cardiac arrest (aHR 8.180, 95% CI 3.382-19.785, p<0.001) and unfit patient status (aHR 6.420, 95% CI 1.876-21.965, p=0.003) emerged as independent predictors of 30-day mortality (Table 2).

No significant differences were observed between the pre- and post-protocol groups in terms of estimated blood loss, blood replacement, use of aortic balloon occlusion, length of procedure, ICU stay, or hospital stay (Table 3).

The post-protocol group demonstrated significant reductions in postoperative complications, notably myocardial ischemia (7.2% vs 21.2%, p=0.015) and

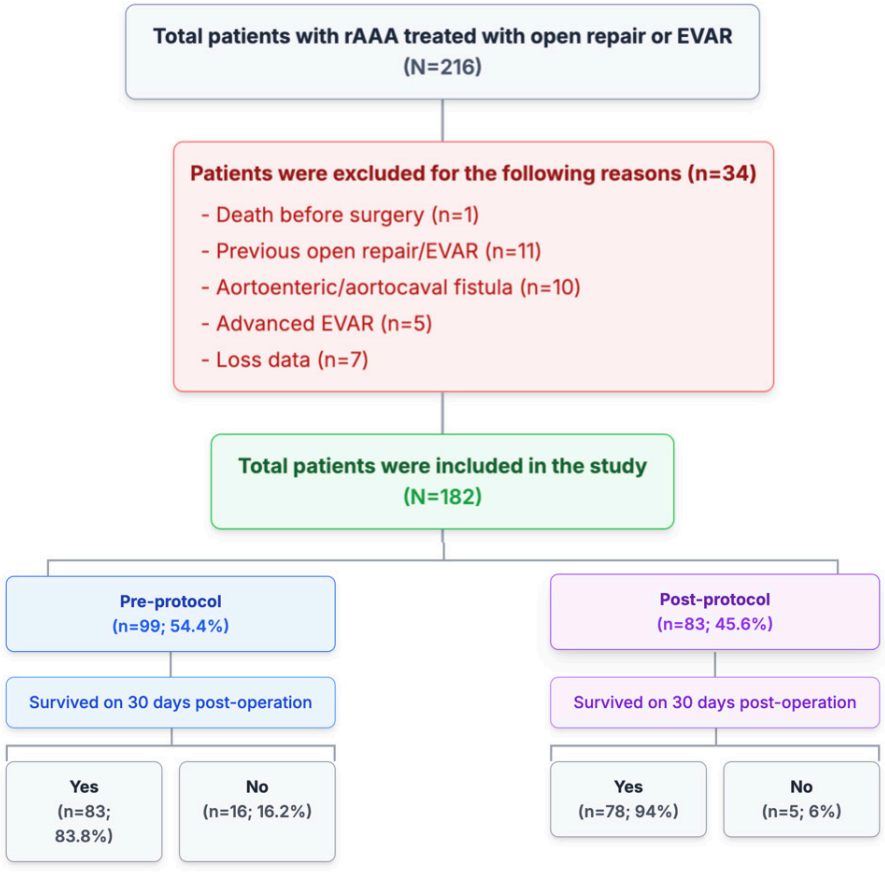

Fig 2. Patient flow and survival rates for AAA treatment with open repair or EVAR.

TABLE 1. Demographic and clinical characteristics of patients before and after implementation of the multidisciplinary protocol.

Characteristic	Total (n=182)	Pre-Protocol (n=99)	Post-Protocol (n=83)	P-value
Demographics				
Age (years); mean ± SD	72.3 ± 10.7	71.5 ± 11.3	73.3 ± 10.0	0.280
Age > 80 years; n (%)	38 (20.9%)	16 (16.2%)	22 (26.5%)	0.127
Male sex; n (%)	153 (84.1%)	85 (85.9%)	68 (81.9%)	0.604
Comorbidities				
Hypertension; n (%)	136 (74.7%)	73 (73.7%)	63 (75.9%)	0.870
Dyslipidemia; n (%)	55 (30.2%)	23 (23.2%)	32 (38.6%)	**0.038**
Type 2 Diabetes mellitus; n (%)	35 (19.2%)	16 (16.2%)	19 (22.9%)	0.338
Coronary artery disease; n (%)	30 (16.5%)	16 (16.2%)	14 (16.9%)	1.000
Cerebrovascular disease; n (%)	16 (8.8%)	7 (7.1%)	9 (10.8%)	0.527
Renal insufficiency; n (%)	40 (22.0%)	22 (22.2%)	18 (21.7%)	1.000
COPD; n (%)	16 (8.8%)	11 (11.1%)	5 (6.0%)	0.345
Current smoking; n (%)	26 (14.3%)	16 (16.2%)	10 (12.0%)	0.564
Clinical Presentation				
Unfit patient status; n (%)	83 (45.6%)	55 (55.6%)	28 (33.7%)	**0.005**
Hemodynamic instability; n (%)	76 (41.8%)	44 (44.4%)	32 (38.6%)	0.515
Cardiac arrest; n (%)	16 (8.8%)	11 (11.1%)	5 (6.0%)	0.345
Transferred from other hospitals; n (%)	146 (80.2%)	79 (79.8%)	67 (80.7%)	1.000
Laboratory Parameters				
Hemoglobin (g/dl); mean ± SD	9.6 (2.2%)	9.8 (2.1%)	9.5 (2.2%)	0.363
Hematocrit (%); mean ± SD	29.4 (6.4%)	29.7 (6.4%)	29.0 (6.6%)	0.456
Creatinine (mg/dl); median (min, max)	1.5 (0.1, 9.6)	1.6 (0.1, 9.0)	1.5 (0.5, 9.6)	0.426

Statistically significant P-values are in bold

Abbreviations: COPD, chronic obstructive pulmonary disease; SD, standard deviation

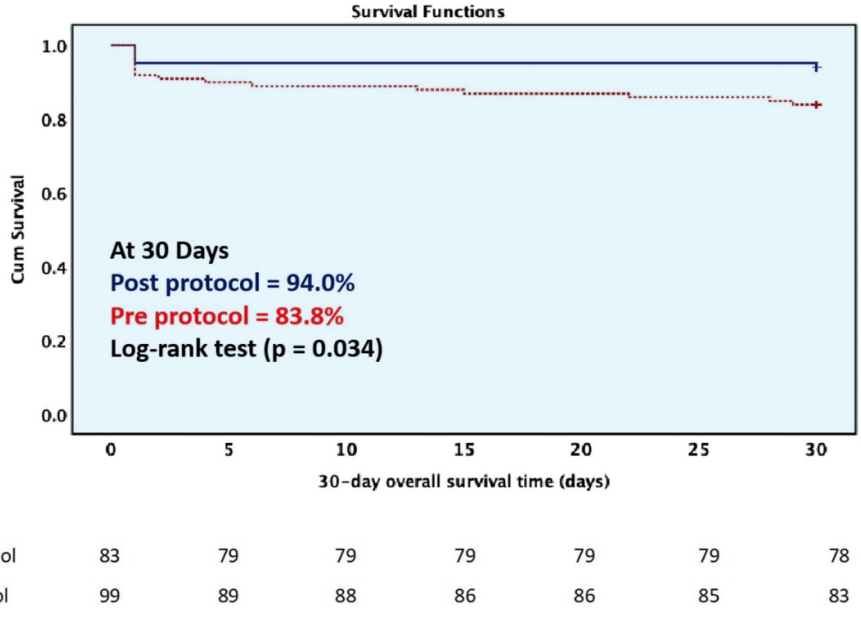

Fig 3. Kaplan-Meier curves illustrating 30-day overall survival in patients with rAAA.

TABLE 2. Univariable and multivariable Cox proportional hazards analyses of factors associated with 30-day overall survival.

Factor	Univariable Model		Multivariable Model	
	Unadjusted HR (95% CI)	P-value	Adjusted HR (95% CI)	P-value
Protocol Implementation		**0.046**		0.461
Post-protocol	1.000 (Reference)		1.000 (Reference)	
Pre-protocol	2.778 (1.018, 7.585)		1.491 (0.515, 4.314)	
Clinical Factors				
Dyslipidemia	0.712 (0.261, 1.944)	0.508	0.580 (0.211, 1.594)	0.291
Unfit patient status	7.701 (2.267, 26.159)	**0.001**	6.420 (1.876, 21.965)	**0.003**
Hemodynamic instability	4.829 (1.768, 13.192)	0.002	2.503 (0.794, 7.891)	0.117
Cardiac arrest	10.125 (4.222, 24.282)	**<0.001**	8.180 (3.382, 19.785)	**<0.001**

Abbreviations: HR, hazard ratio; CI, confidence interval
Values <1.0 indicate factors associated with improved survival; values >1.0 indicate factors associated with increased mortality risk
Statistically significant P-values are in bold

TABLE 3. Intraoperative and postoperative characteristics before and after implementation of the multidisciplinary protocol.

Variable	Total (n=182)	Pre-Protocol (n=99)	Post-Protocol (n=83)	P-value
Intraoperative Parameters				
Estimated blood loss (ml); median (min, max)	700 (20, 22500)	500 (20, 21000)	1000 (20, 22500)	0.300
Estimated blood loss > 2000 ml; n (%)	59 (32.4%)	30 (30.3%)	29 (34.9%)	0.612
Blood replacement (Units); median (min, max)	4 (0, 40)	4 (0, 19)	4 (0, 40)	0.521
Aortic balloon occlusion; n (%)	70 (38.5%)	39 (39.4%)	31 (37.3%)	0.897
Procedure duration (minutes); median (min, max)	180 (35, 530)	180 (55, 530)	180 (35, 435)	0.425
Postoperative Course				
ICU length of stay (days); median (min, max)	4.5 (0, 90)	4 (0, 90)	5 (0, 64)	0.412
Hospital length of stay (days); median (min, max)	15 (1, 221)	16 (1, 189)	15 (1, 221)	0.865

Abbreviation: ICU, intensive care unit

septicemia (1.2% vs 20.2%, p<0.001), compared to the pre-protocol group. No significant differences were observed in other complications (Tables 4 and 5).

Subgroup analysis

When stratified by repair technique, both EVAR and OSR demonstrated trends toward reduced 30-day mortality during the post-protocol period. EVAR mortality decreased from 18.1% to 6.8%, whereas OSR mortality fell from 11.1% to 5.1%. Regarding complications, no significant difference was observed between EVAR and OSR during either the pre- or post-protocol period.

TABLE 4. Postoperative complications before and after implementation of the multidisciplinary protocol.

Complication	Total (n=182)	Pre-Protocol (n=99)	Post-Protocol (n=83)	P-value
Organ-Related Complications				
Myocardial ischemia; n (%)	27 (14.8%)	21 (21.2%)	6 (7.2%)	**0.015**
Congestive heart failure; n (%)	14 (7.7%)	6 (6.1%)	8 (9.6%)	0.533
Respiratory failure; n (%)	22 (12.1%)	9 (9.1%)	13 (15.7%)	0.260
Renal failure requiring hemodialysis; n (%)	31 (17.0%)	19 (19.2%)	12 (14.5%)	0.517
Ischemic colitis; n (%)	17 (9.3%)	9 (9.1%)	8 (9.6%)	1.000
Abdominal compartment syndrome; n (%)	41 (22.5%)	21 (21.2%)	20 (24.1%)	0.775
Wound dehiscence; n (%)	4 (2.2%)	2 (2.0%)	2 (2.4%)	1.000
Infectious Complications				
Chest infection; n (%)	42 (23.1%)	28 (28.3%)	14 (16.9%)	0.100
Wound infection; n (%)	8 (4.4%)	7 (7.1%)	1 (1.2%)	0.119
Intraabdominal infection; n (%)	6 (3.3%)	4 (4.0%)	2 (2.4%)	0.690
Graft infection; n (%)	2 (1.1%)	2 (2.0%)	0 (0%)	0.501
Septicemia; n (%)	21 (11.5%)	20 (20.2%)	1 (1.2%)	**<0.001**
Urinary tract infection; n (%)	6 (3.3%)	2 (2.0%)	4 (4.8%)	0.414
Other				
Perioperative reintervention; n (%)	45 (24.7%)	20 (20.2%)	25 (30.1%)	0.170

Statistically significant P-values are in bold

TABLE 5. Comparison of complications between EVAR and OSR in pre- and post-protocol periods.

Complication	Pre-Protocol				Post-Protocol			
	Total	EVAR	OSR	P-value	Total	EVAR	OSR	P-value
Cardiac/Pulmonary								
Myocardial ischemia; n (%)	21 (21.2%)	17 (23.6%)	4 (14.8%)	0.498	6 (7.2%)	5 (11.4%)	1 (2.6%)	0.207
Congestive heart failure; n (%)	6 (6.1%)	4 (5.6%)	2 (7.4%)	0.663	8 (9.6%)	5 (11.4%)	3 (7.7%)	0.717
Respiratory failure; n (%)	9 (9.1%)	5 (6.9%)	4 (14.8%)	0.251	13 (15.7%)	7 (15.9%)	6 (15.4%)	1.000
Renal/Gastrointestinal								
Renal failure requiring hemodialysis; n (%)	19 (19.2%)	11 (15.3%)	8 (29.6%)	0.184	12 (14.5%)	5 (11.4%)	7 (17.9%)	0.590
Ischemic colitis; n (%)	9 (9.1%)	7 (9.7%)	2 (7.4%)	1.000	8 (9.6%)	6 (13.6%)	2 (5.1%)	0.272
Abdominal compartment syndrome; n (%)	21 (21.2%)	14 (19.4%)	7 (25.9%)	0.670	20 (24.1%)	11 (25.0%)	9 (23.1%)	1.000
Infectious								
Chest infection; n (%)	28 (28.3%)	20 (27.8%)	8 (29.6%)	1.000	14 (16.9%)	7 (15.9%)	7 (17.9%)	1.000
Wound infection; n (%)	7 (7.1%)	5 (6.9%)	2 (7.4%)	1.000	1 (1.2%)	1 (2.3%)	0	1.000
Intraabdominal infection; n (%)	4 (4.0%)	3 (4.2%)	1 (3.7%)	1.000	2 (2.4%)	2 (4.5%)	0	0.496
Graft infection; n (%)	2 (2.0%)	2 (2.8%)	0	1.000	0	0	0	-
Septicemia; n (%)	20 (20.2%)	15 (20.8%)	5 (18.5%)	1.000	1 (1.2%)	1 (2.3%)	0	1.000
Urinary tract infection; n (%)	2 (2.0%)	2 (2.8%)	0	1.000	4 (4.8%)	3 (6.8%)	1 (2.6%)	0.619
Other								
Wound dehiscence; n (%)	2 (2.0%)	1 (1.4%)	1 (3.7%)	0.473	2 (2.4%)	2 (4.5%)	0	0.496
Perioperative reintervention; n (%)	20 (20.2%)	15 (20.8%)	5 (18.5%)	1.000	25 (30.1%)	16 (36.4%)	9 (23.1%)	0.28

Abbreviations: EVAR, endovascular aneurysm repair; OSR, open surgical repair

DISCUSSION

This 13-year retrospective cohort study demonstrates that implementation of a comprehensive multidisciplinary protocol for managing rAAA is associated with significantly improved 30-day survival rates and reduced postoperative complications. Our findings underscore the potential of structured, team-based approaches to enhance outcomes in time-critical vascular emergencies. However, in multivariable analysis, protocol implementation was associated with only a non-significant reduction in mortality.

The potential for such significant mortality reduction challenges the traditionally high mortality rates associated with rAAA, which have been reported to range from 50% to 80% in various studies.[11,12] The observed reduction in 30-day mortality from 16.2% to 6.0% after protocol implementation is remarkable and exceeds improvements reported in previous studies. For instance, Takei et al. observed a decrease in mortality from 22.5% to 9.6% after introducing an endovascular-first protocol.[13] In contrast, the IMPROVE trial reported a 30-day mortality rate of 35.4% for endovascular strategy and 37.4% for open repair.[14] Our more substantial improvement may be attributed to the comprehensive nature of our protocol, which encompassed not only treatment selection but also streamlined processes, enhanced communication, and standardized postoperative care.

The protocol's significant reductions in major postoperative complications, particularly myocardial ischemia and septicemia, indicate benefits beyond immediate survival. This comprehensive improvement in outcomes can be attributed to several factors: rapid mobilization of a multidisciplinary team, standardized decision-making processes, preparedness for both EVAR and OSR, proactive measures like massive transfusion protocols and aortic balloon occlusion preparation, and streamlined postoperative care. These elements, which align with recent guidelines and expert consensus statements on rAAA management,[15,16] collectively contribute to swift, coordinated care, optimized treatment selection, reduced delays, improved hemodynamic stability, reduced end-organ damage, and earlier recognition and management of complications.

The reduction in myocardial ischemia is consistent with studies showing that protocolized care can improve cardiac outcomes in high-risk surgical patients.[17] However, our improvement exceeds that reported in many studies, warranting further investigation into the specific elements of our protocol that may have contributed to this outcome.

The trend towards increased use of endovascular aortic repair (EVAR) in our study mirrors global patterns in rAAA management.[8] EVAR is frequently employed as the initial treatment strategy for rAAA in many institutions, given its reported benefits in patient outcomes. However, unlike some studies that attribute improved outcomes solely to the adoption of EVAR,[3] our results suggest that a comprehensive protocol can enhance outcomes across both EVAR and open surgical repair (OSR). Furthermore, the post-protocol group exhibited a notable increase in the proportion of open surgical repair (OSR) for rAAA patients (pre-protocol: 27% vs post-protocol: 47%). This shift is likely attributable to the protocolized use of advanced preoperative imaging, which facilitates enhanced patient selection for the most appropriate operative approach. So, patient with anatomy suitable for EVAR underwent EVAR, whereas those without suitable for EVAR underwent open surgical repair

Our multivariable analysis identified cardiac arrest (aHR 8.180, 95% CI 3.382-19.785) and unfit patient status (aHR 6.420, 95% CI 1.876-21.965) as independent predictors of 30-day mortality. These findings are consistent with previous studies[18,19] and highlight the critical importance of rapid assessment and intervention in rAAA cases, as well as the need for careful patient selection and optimization when possible. The strong association between cardiac arrest and mortality underscores the time-sensitive nature of rAAA management and supports the emphasis our protocol places on rapid activation of the multidisciplinary team and streamlined transfer processes. The impact of patient fitness on outcomes highlights the potential benefit of prehabilitation programs for high-risk patients with known AAAs, although the emergency nature of rAAA often precludes such interventions.

While our study provides compelling evidence for the benefits of a multidisciplinary protocol in rAAA management, we acknowledge several limitations. First, as a single-center study, our results may not be fully generalizable to all healthcare settings. Second, the observational nature of the study precludes definitive causal inferences about the protocol's impact. Third, evolving technology, increased operation expertise and general improvements in critical care over the study period may have contributed to the observed outcomes.

Future research should focus on validating these findings in multicenter, randomized controlled trials. Additionally, investigating the long-term outcomes and cost-effectiveness of protocol-driven rAAA management would provide valuable insights for healthcare policy and resource allocation. Exploring the potential of artificial intelligence and machine learning in refining risk stratification and decision-making processes for rAAA could also be a fruitful avenue for future studies.[20]

CONCLUSION

In conclusion, our study supports that a comprehensive multidisciplinary protocol for rAAA management can reduce postoperative complications and improve short-term survival, despite multivariable analysis showing a non-significant reduction in mortality. These findings have important implications for vascular surgery practice and highlight the potential of systems-based approaches to enhance outcomes in acute care settings. As the landscape of rAAA management continues to evolve, embracing standardized, team-based protocols may be key to further reducing mortality and morbidity in this challenging patient population.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Conflict of Interest

All authors declare that they have no personal or professional conflicts of interest, and received no financial support from the companies that produce and distribute the drugs, devices, or materials described in this report.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization and methodology, K.C., N.P., and N.T.; Investigation, N.T., C.R., C.W., K.H., N.S., S.H., T.P., K.P.; Formal analysis, S.T., N.T., K.C.; Visualization and writing – N.P., N.T., K.C. original draft, N.T., K.C; Writing – review and editing, N.P., N.T., K.C.; Supervision, K.C. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

None.

REFERENCES

1. Prapassaro T, Chinsakchai K, Techarattanaprasert S, Wongwanit C, Ruansetakit C, Hongku K, et al. Determining Perioperative Mortality in Patients with Ruptured Abdominal Aortic Aneurysm: Insights from a Retrospective Cohort Study. Siriraj Med J. 2024; 76(8):480-7.
2. Sweeting MJ, Balm R, Desgranges P, Ulug P, Powell JT. Individual-patient meta-analysis of three randomized trials comparing endovascular versus open repair for ruptured abdominal aortic aneurysm. Br J Surg. 2015;102(10):1229-39.
3. van Beek SC, Conijn AP, Koelemay MJ, Balm R. Editor's Choice - Endovascular aneurysm repair versus open repair for patients with a ruptured abdominal aortic aneurysm: a systematic review and meta-analysis of short-term survival. Eur J Vasc Endovasc Surg. 2014;47(6):593-602.
4. Moore R, Nutley M, Cina CS, Motamedi M, Faris P, Abuznadah W. Improved survival after introduction of an emergency endovascular therapy protocol for ruptured abdominal aortic aneurysms. J Vasc Surg. 2007;45(3):443-50.
5. Azhar B, Patel SR, Holt PJ, Hinchliffe RJ, Thompson MM, Karthikesalingam A. Misdiagnosis of ruptured abdominal aortic aneurysm: systematic review and meta-analysis. J Endovasc Ther. 2014;21(4):568-75.
6. Bown MJ, Sutton AJ, Bell PR, Sayers RD. A meta-analysis of 50 years of ruptured abdominal aortic aneurysm repair. Br J Surg. 2002;89(6):714-30.
7. Mell MW, Callcut RA, Bech F, Delgado MK, Staudenmayer K, Spain DA, et al. Predictors of emergency department death for patients presenting with ruptured abdominal aortic aneurysms. J Vasc Surg 2012;56(3):651-5.
8. Kontopodis N, Galanakis N, Antoniou SA, Tsetis D, Ioannou CV, Veith FJ, et al. Meta-Analysis and Meta-Regression Analysis of Outcomes of Endovascular and Open Repair for Ruptured Abdominal Aortic Aneurysm. Eur J Vasc Endovasc Surg. 2020;59(3):399-410.
9. Wanhainen A, Verzini F, Van Herzeele I, Allaire E, Bown M, Cohnert T, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. Eur J Vasc Endovasc Surg. 2019;57(1):8-93.
10. Brown LC, Epstein D, Manca A, Beard JD, Powell JT, Greenhalgh RM. The UK Endovascular Aneurysm Repair (EVAR) trials: design, methodology and progress. Eur J Vasc Endovasc Surg. 2004;27(4):372-81.
11. Reimerink JJ, van der Laan MJ, Koelemay MJ, Balm R, Legemate DA. Systematic review and meta-analysis of population-based mortality from ruptured abdominal aortic aneurysm. Br J Surg. 2013;100(11):1405-13.
12. Karthikesalingam A, Holt PJ, Vidal-Diez A, Ozdemir BA, Poloniecki JD, Hinchliffe RJ, et al. Mortality from ruptured

abdominal aortic aneurysms: clinical lessons from a comparison of outcomes in England and the USA. Lancet. 2014;383(9921):963-9.
13. Takei Y, Tezuka M, Saito S, Ogasawara T, Seki M, Kato T, et al. A protocol-based treatment for ruptured abdominal aortic aneurysm contributed to improving aorta-related mortality: a retrospective cohort study. BMC Cardiovasc Disord. 2023;23(1):436.
14. Comparative clinical effectiveness and cost effectiveness of endovascular strategy v open repair for ruptured abdominal aortic aneurysm: three year results of the IMPROVE randomised trial. BMJ. 2017;359:j4859.
15. D'Oria M, Lembo R, Hörer TM, Rasmussen T, Mani K, Parlani G, et al. An International Expert-Based CONsensus on Indications and Techniques for aoRtic balloOn occLusion in the Management of Ruptured Abdominal Aortic Aneurysms (CONTROL-RAAA). J Endovasc Ther. 2023:15266028231217233.
16. Scali ST, Stone DH. Modern management of ruptured abdominal aortic aneurysm. Front Cardiovasc Med. 2023;10:1323465.
17. Duceppe E, Parlow J, MacDonald P, Lyons K, McMullen M, Srinathan S, et al. Canadian Cardiovascular Society Guidelines on Perioperative Cardiac Risk Assessment and Management for Patients Who Undergo Noncardiac Surgery. Can J Cardiol. 2017;33(1):17-32.
18. Salhab M, Farmer J, Osman I. Impact of delay on survival in patients with ruptured abdominal aortic aneurysm. Vascular. 2006;14(1):38-42.
19. Harris DG, Garrido D, Oates CP, Kalsi R, Huffner ME, Toursavadkohi S, et al. Repair of ruptured abdominal aortic aneurysm after cardiac arrest. J Vasc Surg. 2016;64(5):1497-502.
20. Guni A, Varma P, Zhang J, Fehervari M, Ashrafian H. Artificial Intelligence in Surgery: The Future is Now. Eur Surg Res. 2024;65(1):22-39.

Microwave Oven vs Level-1 Rapid Fluid Warmer: A Comparative Efficacy Study of Fluid Warming in the ATLS Protocol (MOLEWA Study)

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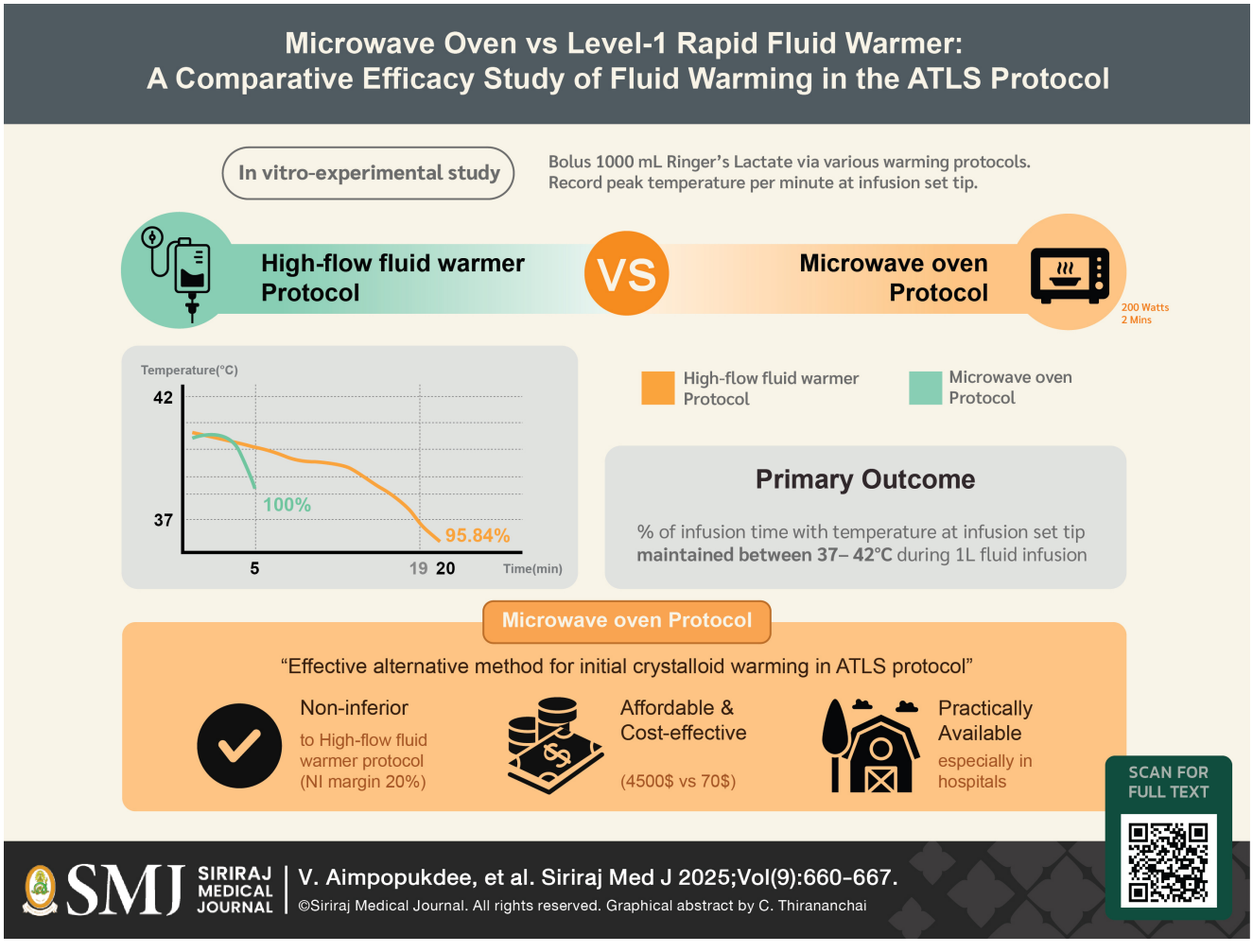

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ABSTRACT

Objective: Although the use of a microwave for fluid warming has been proposed, standardized protocols for its clinical application remain limited. The purpose of this study is to evaluate the effectiveness of microwave-based fluid warming compared to conventional fluid warming equipment.

Materials and Methods: This in-vitro experimental study was conducted in two phases. In the pilot trial, we compared five groups using different combinations of container types, infusion rates, and warming techniques. In the second phase, a non-inferiority trial, two groups of 18 1-liter isotonic crystalloid bottles were compared: one using the Level-1 H-1200 fluid warmer and the other employing a microwave oven warming protocol (800W, two minutes at maximum power). The primary outcome was the percentage of infusion time during which the fluid temperature at the tip of the infusion set remained within the target range of 37°C to 42°C.

Results: The warming cabinet and microwave oven achieved mean infusion durations of 5.0 and 19.5 minutes, respectively. The Level-1 group maintained the target temperature for 100% of the infusion duration, while the microwave group achieved a rate of 95.84% [95.82%-95.86%], demonstrating non-inferiority to the Level-1 method.

Conclusion: Microwave fluid warming is a feasible, practical, and cost-effective alternative to conventional fluid warming equipment. Its comparable warming efficiency and wide availability support its potential use in rural areas with limited resources.

Keywords: Microwave; fluid warming; trauma; initial management (Siriraj Med J 2025; 77: 660-667)

Abbreviation

ATLS - Advanced Trauma Life Support

INTRODUCTION

Advanced Trauma Life Support (ATLS) and other trauma care standards emphasize the importance of administering warm intravenous (IV) fluids to avoid the lethal triad of acidosis, coagulopathy, and hypothermia. High-flow fluid warmers are effective in maintaining the recommended fluid temperature of 39°C, particularly in geriatric patients.[1,2] However, their high cost and logistical challenges may limit their practicality, especially in resource-constrained settings. As a result, microwave ovens are being investigated as a potential alternative for fluid warming. They offer a practical, low-cost option that may simplify trauma care.

The concept of using microwave ovens to warm crystalloid fluids emerged in 1984[3], with subsequent in vitro studies examining various parameters including microwave models, power settings, heating durations, and flow rates.[4-8] Research has confirmed the safety of microwaving crystalloid fluids packaged in polypropylene, as its melting point exceeds 130°C and is FDA-approved for microwave food contact.[9,10] However, microwave ovens are not FDA-approved for warming IV fluids, as they are not designed to ensure uniform heating or prevent overheating, which can lead to patient harm. The FDA advises against microwave use for fluid warming due to risks such as hot spots, bag rupture, and unpredictable temperature control. However, in resource-limited or emergency settings where approved fluid warmers are unavailable, a general-use microwave may be used with extreme caution, following strict protocol. For this reason, the ATLS guidelines suggest that a microwave may be considered as an alternative method for fluid warming when standard fluid warmers are unavailable, provided appropriate safety precautions are followed. However, this method is exclusively recommended for crystalloid fluids. Blood products are not suitable for microwave warming, as hemolysis can occur at temperatures above 42-43°C.[11] Additionally, some studies have reported complications, such as burns and venous thrombosis, associated with overheated fluids.[12,13]

This study aims to address the lack of established protocols and limited evidence by rigorously comparing microwave-based fluid warming with conventional high-flow fluid warmer methods. Using a two-phase approach — beginning with a pilot trial to explore various warming techniques, followed by a non-inferiority trial — the research evaluates effectiveness, infusion time, and cost considerations. The primary outcome is the maintenance of target fluid temperatures throughout administration.

MATERIALS AND METHODS

This study employed an in-vitro experimental design to comprehensively assess the efficacy of microwave oven fluid warming compared to the high-flow fluid warmer

systems in the context of trauma care. The study was conducted at a Level 1 trauma center equipped with multiple types of fluid warming machines and equipment.

Sample size calculation:

The sample size for the non-inferiority trial was determined based on the following parameters: *Pilot Study Sample Size* (from a prior microwave protocol infusion study; six participants per arm, *Significance Level* (alpha, one-sided): 0.025 (corresponding to a 2.5% significance level), *Standard Proportion* (from pilot data): 0.99, *Equivalence Limit Difference (Margin of Non-Inferiority)*: -0.2, *Expected Proportion*: 0.95, and the *Expected Difference* (difference to detect): -0.04. We set the power at 80% (corresponding to a beta of 0.20). Using these values, along with the provided proportions: the sample size was 18 for each group.

A 20% non-inferiority margin was established to determine acceptable differences in the proportion of time fluid temperature remained within the target range (37°C-42°C). This margin was considered clinically acceptable given the potential advantages of the alternative warming device, including cost-effectiveness, portability, and reduced setup time. The selected margin aligns with previous studies of perioperative warming technologies, which have employed non-inferiority thresholds of 10-20% for devices with comparable safety profiles.[14,15] Additionally, NICE guideline NG65 endorses practical, cost-efficient warming methods when thermal performance is equivalent across devices.[16] The 20% margin was therefore deemed clinically and operationally appropriate for this device comparison.

Study design and setting

Initial phase:

The initial phase of the study consisted of a pilot trial designed to explore a variety of fluid warming techniques and identify optimal conditions for subsequent evaluation. Seven distinct groups were formed, each characterized by differences in container types, infusion techniques, and temperature maintenance strategies. These included four microwave oven methods, two warm cabinet methods, and one high-flow fluid warmer method. The study investigated 1-liter of Ringer lactate solution containers made of standard polypropylene, including both rigid and soft intravenous bags. Infusion techniques ranged from free-flow infusion to syringe-push delivery using an 18-gauge Cathlon catheter, simulating different clinical scenarios with varying urgency of fluid administration. Temperature maintenance strategies included microwave-based warming and the warm cabinet approach.

Non-inferiority trial:

Informed by the pilot trial findings, a non-inferiority trial was subsequently designed to compare the performance of microwave fluid warming to the established high-flow fluid warming protocol. A total of 36 bottles of 1-liter isotonic crystalloid solution were used — 18 for each method. For the high-flow warming group, the Smith Medical Level 1 H-1200 fluid warmer was used, which is a widely accepted device known for its precision in maintaining fluid temperature during infusion.

For the microwave warming group, a standardized protocol was developed. In this protocol, each fluid bottle was heated in a microwave oven, calibrated to 800W, for a duration of two minutes. The temperature at the tip of the infusion set was measured using a digital thermometer.

Outcome measures:

The primary outcome measure of this study was the percentage of infusion time during which the temperature at the tip of the infusion set remained within the optimal range of 37-42°C. Temperature readings were obtained using a Fluke 179 RMS Multimeter, with the probe positioned at the tip of the infusion set, representing the point of connection to the patients. This measure served as a critical indicator of each warming protocol's ability to deliver warm IV fluids as mandated by the ATLS protocol.

Data collection and analysis:

Data collection was conducted by a team of trained healthcare professionals to ensure precision and consistency. Temperature measurements were recorded at one-minute intervals throughout the administration of each 1-liter fluid unit, allowing for the calculation of the percentage of infusion time that fell within the target temperature range.

Descriptive statistics, including means, standard deviations, and confidence intervals, were calculated to summarize the performance of each warming protocol. Inferential statistical analyses, including t-tests and non-inferiority testing, were conducted to compare the two methods and determine non-inferiority based on a predetermined margin derived from the pilot trial. All data were collected and analyzed using IBM SPSS Statistics 28 (IBM Corporation, Armonk, NY).

Ethical considerations:

Ethical exemption for this in-vitro experimental study was obtained from the Institutional Review Board. The study adhered to all relevant ethical guidelines and

regulations to ensure the responsible and respectful conduct of research.

RESULTS

Pilot trial:

The pilot trial evaluated a range of fluid warming techniques, each characterized by variations in container types, infusion rates, and temperature maintenance strategies. The average warming efficacy across the various protocols is illustrated in Fig 1.

Among the tested methods, protocols 1, 2, 3, and 5 demonstrated efficacy rates of 96.71%, 85.12%, 100%, and 25%, respectively. However, protocols 4 and 6 were terminated prematurely due to critical safety concerns: fluid temperatures exceeded the upper safety limit of 42°C within the initial minutes of operation, often reaching 44-46°C. This overheating necessitated discontinuation of these protocols.

Given the practicality and efficacy of protocol 1, it was selected for further investigation in the non-inferiority study against the established high-flow fluid warming protocol. In contrast, although protocol 3 exhibited the highest efficacy, it required rapid infusion of an entire 1-liter crystalloid solution, a condition deemed impractical for real-world application. These results underscore the importance of evaluating not only the efficacy but also the safety of fluid warming protocols, particularly in high-stakes trauma care scenarios.

Non-inferiority trial:

In the non-inferiority trial, each fluid method was meticulously evaluated for its ability to maintain the target temperature range during the infusion of isotonic crystalloid solutions. The high-flow fluid warmer group achieved a 100% maintenance rate, ensuring that the temperature at the tip of the infusion set remained within the optimal range of 37-42°C throughout the entire fluid administration process. This consistent robust performance reaffirmed the high-flow fluid warmer's effectiveness in precise temperature control.

Conversely, the microwave oven warming protocol, using rigid polypropylene crystalloid solution containers heated at 800W for two minutes, also demonstrated remarkable ability to rapidly attain the desired temperature. The mean warming time for the microwave method was 19.43 minutes, and the temperature maintenance rate was 95.84% (95.82-95.86, SD 0.04), indicating reliable performance. The standard deviation of temperature measurements was 0.04°C. Detailed results are illustrated in Fig 2.

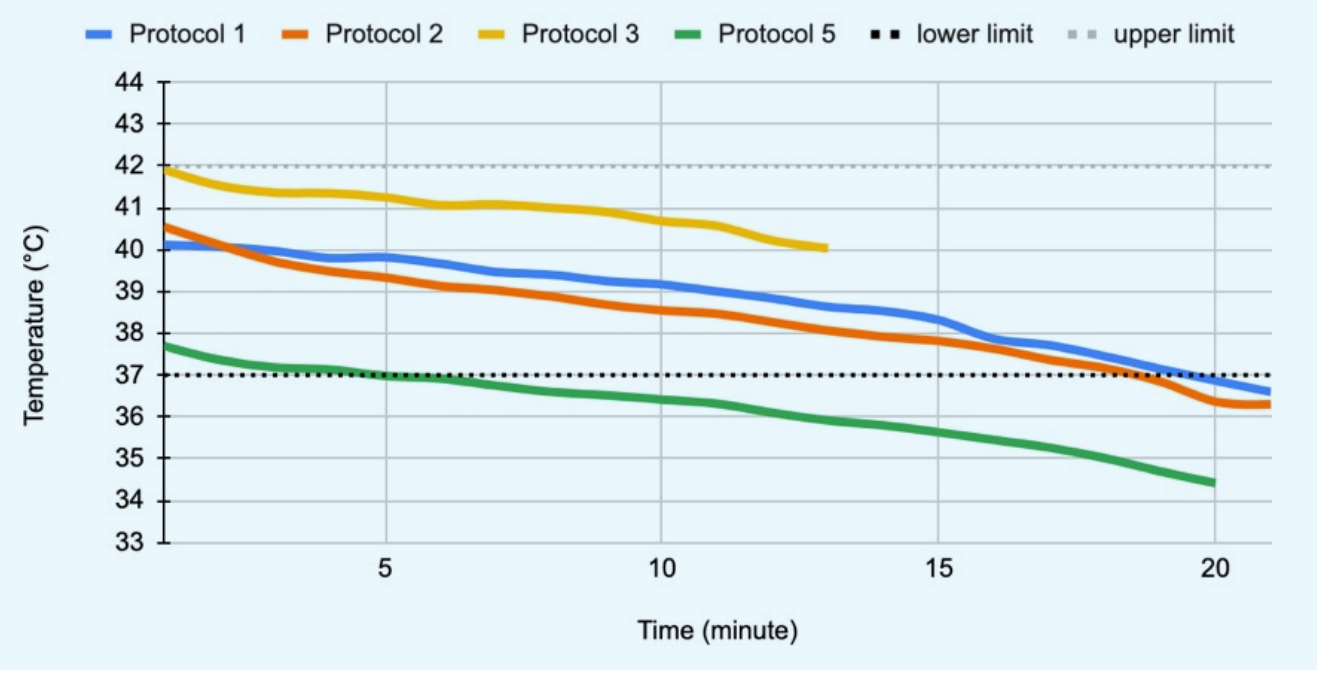

Fig 1. Temperature control comparison across different warming protocols
Protocol 1: Microwave oven, 800 W for 2 mins, rigid 1-liter RLS package, free- flow via Cathlon No.18
Protocol 2: Microwave oven, 800 W for 2 mins, soft 1-liter RLS package, free-flow via Cathlon No.18
Protocol 3: Microwave oven, 800 W for 2 mins, rigid 1-liter RLS package, syringe push via Cathlon No.18
Protocol 4: Microwave oven, 800 W for 3 mins, rigid 1- liter RLS package, free-flow via Cathlon No.18, Prematurely terminated
Protocol 5: Warm cabinet preheated to 40°C for 8 hours, rigid 1-liter RLS package, free-flow via Cathlon No.18
Protocol 6: Warm cabinet preheated to 50°C for 8 hours, rigid 1-liter RLS package, free-flow via Cathlon No.18, Prematurely terminated

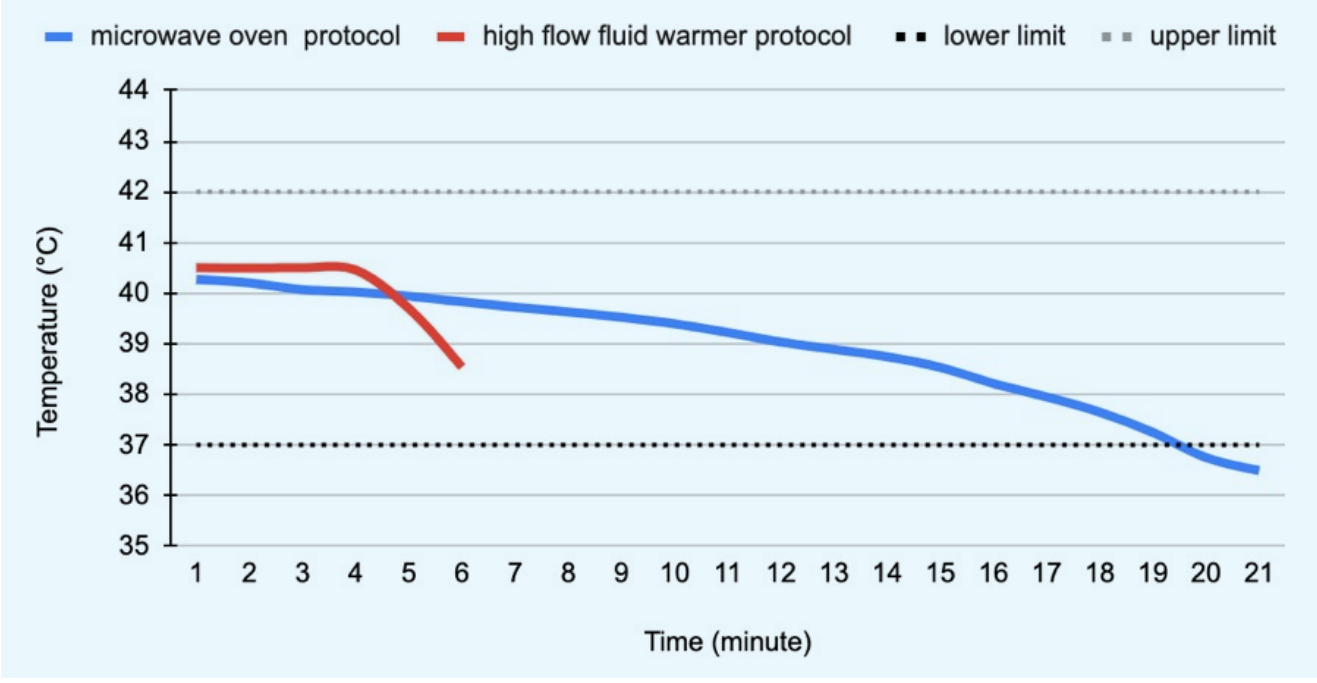

Fig 2. Temperature control comparison between oven protocol and high-flow fluid warmer protocol.

Non-inferiority analysis:

The primary focus of the non-inferiority analysis was to determine whether the microwave fluid warming protocol was non-inferior to the high-flow fluid warming protocol, using a pre-determined non-inferiority margin of 20%, as defined in the pilot trial. Statistical evaluation was performed using appropriate methods, including t-tests and non-inferiority testing. The results demonstrated that the microwave method was non-inferior to the Level-1 method (95.84% vs 100%)

Secondary outcome measures:

Infusion Time: Infusion time was assessed as a key secondary outcome. In the microwave oven warming group, using a free-flowing technique, the mean infusion time was 19.5 minutes. In contrast, the high-flow fluid warming group achieved significantly faster infusion times, averaging 5 minutes per liter.

Overall cost analysis:

An economic comparison of factors associated with each warming protocol was carried out, accounting for initial equipment costs and the cost of disposable infusion sets. The findings revealed a substantial cost difference between the two groups (Table 1). The microwave warming protocol, which encompassed the cost of the microwave oven and disposable infusion sets, had an average procedural cost of approximately $70 per procedure. In contrast, the high-flow fluid warming group incurred considerably higher costs, with an estimated $4,500 per procedure. This substantial cost disparity highlights the significant economic advantage of the microwave oven method.

TABLE 1. Comparative cost analysis of common fluid warming methods in clinical settings.

Device	Estimated unit cost (USD)	Lifespan (Years)	Estimated uses per year	Per-use cost estimate (USD)
Level-1 fluid warmer	$8,000 - $12,000	5 - 7	1,500 - 2,000	~$1.00 - $1.60
Warming cabinet	$3,000 - $5,000	7 - 10	2,000 - 3,000	~$0.20 - $0.40
Microwave	$100 - $300	3 - 5	1,000 - 1,500	~$0.03 - $0.10

DISCUSSION

This study provides a comprehensive evaluation of the viability and effectiveness of microwave fluid warming in trauma care, compared with the well-established high-flow fluid warming technique. The discussion focuses on the implications of these findings on patient outcomes, trauma management procedures, and broader healthcare systems.

Regarding fluid-warming efficacy, the high-flow Level-1 is known for its precision and ability to maintain target temperatures. Hence, it serves as the benchmark against which microwave fluid warming is evaluated. The Level-1 method's ability to consistently achieve a 100% target temperature maintenance underscores its effectiveness in ensuring optimal IV fluid temperatures. This aligns with existing literature supporting the use of specialized fluid warming equipment to prevent the lethal triad in trauma patients. Although the microwave method did not reach the same level of temperature maintenance as the Level-1 method, it demonstrated substantial promise. The microwave technique warmed fluids in just an average of two minutes, highlighting its capacity to swiftly elevate fluid temperatures. This speed may be especially valuable in time-sensitive scenarios, potentially accelerating the initiation of warm fluid administration. Moreover, its ability to maintain the target temperature for 95.84% of the infusion duration indicates the method's clinical utility and effectiveness in ensuring warm fluid delivery for the majority of infusion duration.

To further improve temperature maintenance, several strategies warrant consideration, including insulation of crystalloid packages to mitigate thermal loss and modifying infusion parameters. For example, the use of larger-bore needles or simultaneous infusion of two 500 mL packages may decrease total free-flow infusion time, provided warming protocols are adjusted accordingly. These suggestions could enhance both the efficacy and infusion rate of microwave-based fluid warming, ultimately increasing its clinical applicability in time-critical trauma care settings. Further research and refinement of these strategies could lead to more effective fluid warming techniques and enhance patient care in high-stake medical situations.

Our study emphasized the practical clinical implementation of IV fluid warming. In contrast to Chittawattanarat et al., who investigated optimal microwave parameters under controlled laboratory conditions using various fluids and containers[4], we replicated actual clinical practice by utilizing standard IV fluid bottles connected to infusion sets with needles. This approach accounts for potential heat loss along the IV line, and we measured temperature at the needle tip to reflect the final temperature delivered to the patient. In addition to microwave warming, we compared the efficacy of other commonly used warming protocols. Notably, warming cabinets, despite their widespread use in trauma settings, may be ineffective if fluids are not delivered rapidly (e.g., 1 liter in 5 minutes). This highlights the need to determine optimal cabinet temperature settings that maintain adequate warming without causing overheating or underheating during slower infusions.

From an economic standpoint, the microwave warming approach presents a strong value proposition to medical facilities looking for less expensive options that meet the clinical criteria for trauma resuscitation. A significant cost disparity has major implications for resource allocation, especially at facilities with tight budgets. Furthermore, when compared to specialized fluid warming equipment, microwave ovens — which are widely available in both clinical and residential settings — are more cost-effective and ubiquitous. This can democratize access to fluid warming capabilities across a range of healthcare environments. Future research should explore the cost-utility ratio of both warming approaches and assess how feasible each is for application in different clinical settings, especially in situations with low resource environments, such as rural areas, or in mass casualty situations where access to specialized equipment may be limited.

While the focus of this study was temperature maintenance, it is important to acknowledge safety considerations. The risk of overheating remains a potential concern with microwave fluid warming. It poses a risk of hot spots and overheating, especially at the center of the container, where microwave energy is most concentrated.[4] This can lead to thermal injury, hemolysis, or fluid degradation. The container material also influences heating by absorbing microwave energy unevenly. To reduce risk, fluids should be gently shaken or inverted and allowed to rest briefly after microwaving to promote even heat distribution.[4] Consider verifying that the final temperature is below 42°C before infusion, where feasible. Future research should examine not only temperature maintenance but also patient safety and the incidence of adverse events.

In addition to the risk of overheating, the potential release of microplastics should be considered. Although polypropylene, commonly used in IV bags and tubing, has a high melting point (>130°C) and is FDA-approved for microwave food contact, recent studies have raised concerns. Hussain et al. reported the release of micro-

and nanoplastics from microwaved dairy products in polypropylene containers.[17] More recently, Tarafdar et al. demonstrated microplastic release from standard IV infusion systems, with increased levels observed when infusion pumps were used.[18] These findings suggest that microwave warming of IV fluids may further promote microplastic release. However, no studies have directly examined this risk in the context of IV fluid warming, and the clinical implications remain unknown. Further research is warranted.

As with any study, this investigation is not without limitations. While the present study demonstrates the feasibility and thermal efficiency of microwave-based fluid warming under controlled in-vitro conditions, it is important to acknowledge the limitations in translating these findings directly into clinical practice. Our results indicate that, when all parameters are precisely controlled, microwave warming can deliver fluids within the target temperature range recommended for trauma resuscitation. However, in real-world clinical settings, variables such as ambient temperature, infusion tubing length, flow rates, patient core temperature, and individual thermoregulatory responses may significantly affect the temperature of the infused fluid at the point of delivery. Additionally, we acknowledge that the Level 1 system includes both warming and pressurized infusion, while the microwave method relied on free-flow alone. This flow difference may have affected temperature maintenance, potentially disadvantaging the microwave group, though it was not found to be inferior. Our model also excluded vascular resistance, which in clinical settings may slow flow further. If 1 liter cannot be delivered within 19 minutes, the fluid may not reach the target temperature. Moreover, microwave warming of IV fluids is not currently recommended by the FDA due to limited evidence and concerns about overheating from inconsistent temperature control. While existing data may be outdated and high-quality studies are lacking, the potential for harm prevents formal recommendation of this method. As such, further in-vivo investigations are warranted to assess the clinical efficacy, safety, and practicality of this technique before it can be recommended for routine use in patient care.

CONCLUSION

In conclusion, using a microwave to warm fluids is non-inferior to a conventional high-flow fluid warming device. Microwave fluid warming during early trauma resuscitation is feasible, especially in remote areas with limited resources. Additionally, this method costs less. However, further in-vivo studies are warranted to evaluate the efficacy and assess outcomes.

Data Availability Statement

Data supporting this study is available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors (VA, SM, AB, TW, CS, RC, and NO) have no conflicts of interest or disclosures of funding to declare.

Registration Number of Clinical Trial

None.

Author Contribution

Conceptualization and methodology: VA, SM, NO; Investigation: VA, SM, NO; Data analysis: VA, AB, NO; Visualization and writing–original draft: VA, SM, NO; Writing–review and editing: VA, SM, RC, NO; Supervision: RC, NO.; Essentially Intellectual Contributor: SM. All the authors read and agreed with the final version of the manuscript.

Use of Artificial Intelligence

The authors used ChatGPT (OpenAI) to assist with grammar correction and sentence refinement.

REFERENCES

1. American College of Surgeons CoT. Initial Assessment and management. AdvancedTrauma Life Support (ATLS) Course Manual (10th ed.). Chicago, IL: American College of Surgeons; 2018.p.2-22.
2. Somnuke P, Pongraweewan O, Siriussawakul A. Optimizing Perioperative Care for Elderly Surgical Patients: A Review of Strategies and Evidence-Based Practices. Siriraj Med J. 2024; 76(7):465-72.
3. Werwath DL, Schwab CW, Scholten JR, Robinett W. Microwave ovens. A safe new method of warming crystalloids. Am Surg. 1984;50(12):656-9.
4. Chittawatanarat K, Akanitthaphichat S. Microwave oven: how to use it as a crystalloid fluid warmer. J Med Assoc Thai. 2009;

92(11):1428-33.
5. Seo JS, Choi SP, Choi SM, Kim YM, Jeong SK, Lee WJ, et al. Delivery Temperature of Warmed Saline or Blood at Variable Flow Rates. J Korean Soc Emerg Med. 2003;14(1):83-87.
6. Meyer T, Ribeiro M, Mendonça A. Experimental study of adequate microwave warming of crystalloids and derivation of an equation for calculating heating parameters. Rev Bras Cir Plástica. 2012;27:518-22.
7. Marín P, Rincon-Valenzuela D, Monroy-Charry A, Ruiz-Villa J, Higuera-Redondo G, Rubio J. Encuesta de actitudes sobre vigilancia de la temperatura y protección térmicaperioperatoria en Colombia. Rev Colomb Anestesiol. 2016;44.
8. Lindhoff GA, MacG Palmer JH. An assessment of the thermal safety of microwave warming of crystalloid fluids. Anaesthesia. 2000;55(3):251-4.
9. Maddah H. Polypropylene as a promising plastic: a review. Am J Polym Sci. 2016;6(1):1-11.
10. Nutrition C for FS and A. Guidance for Industry: Preparation of PremarketSubmissions for Food Contact Substances (Chemistry Recommendations). Published September 28, 2022. Accessed December 18, 2023. https://www.fda.gov/regulatory-information/search-fda- guidance-documents/guidance-industry-preparation-premarket-submissions-food-contact- substances-chemistry
11. Bettaieb A, Averill-Bates DA. Thermotolerance induced at a fever temperature of 40 degrees C protects cells against hyperthermia-induced apoptosis mediated by death receptor signalling. Biochem Cell Biol Biochim Biol Cell. 2008;86(6):521-38.
12. Cheney FW, Posner KL, Caplan RA, Gild WM. Burns from Warming Devices inAnesthesia: A Closed Claims Analysis. Anesthesiology. 1994;80(4):806-10.
13. Sieunarine K, White GH. Full-thickness burn and venous thrombosis following intravenous infusion of microwave-heated crystalloid fluids. Burns. 1996;22(7):568-9.
14. Kimberger O, Held C, Stadelmann K, Mayer N, Hunkeler C, Sessler DI, Kurz A. Resistive polymer versus forced-air warming: comparable heat transfer and core rewarming rates in volunteers. Anesth Analg. 2008;107(5):1621-6.
15. John M, Crook D, Dasari K, Eljelani F, El-Haboby A, Harper CM. Comparison of resistive heating and forced-air warming to prevent inadvertent perioperative hypothermia. Br J Anaesth. 2016;116(2):249-54.
16. National Institute for Health and Care Excellence (NICE). Hypothermia: prevention and management in adults having surgery. NICE guideline [NG65]. London: NICE; 2016.
17. Hussain KA, Romanova S, Okur I, Zhang D, Kuebler J, Huang X, et al. Assessing the Release of Microplastics and Nanoplastics from Plastic Containers and Reusable Food Pouches: Implications for Human Health. Environ Sci Technol. 2023;57(26):9782-92.
18. Abhrajyoti Tarafdar, Junhao Xie, Aoif Gowen, Amy Claire O'Higgins, Junli Xu. Microplastic Transfer into the Bloodstream from Intravenous Fluid Infusion Systems. Available at http://dx.doi.org/10.2139/ssrn.4709116

A Comparative Study Using CT Imaging and Cadaveric Dissection in the Evaluation of the Posterior Auricular Vein as an Alternative Recipient Vein for Facial and Scalp Reconstructions

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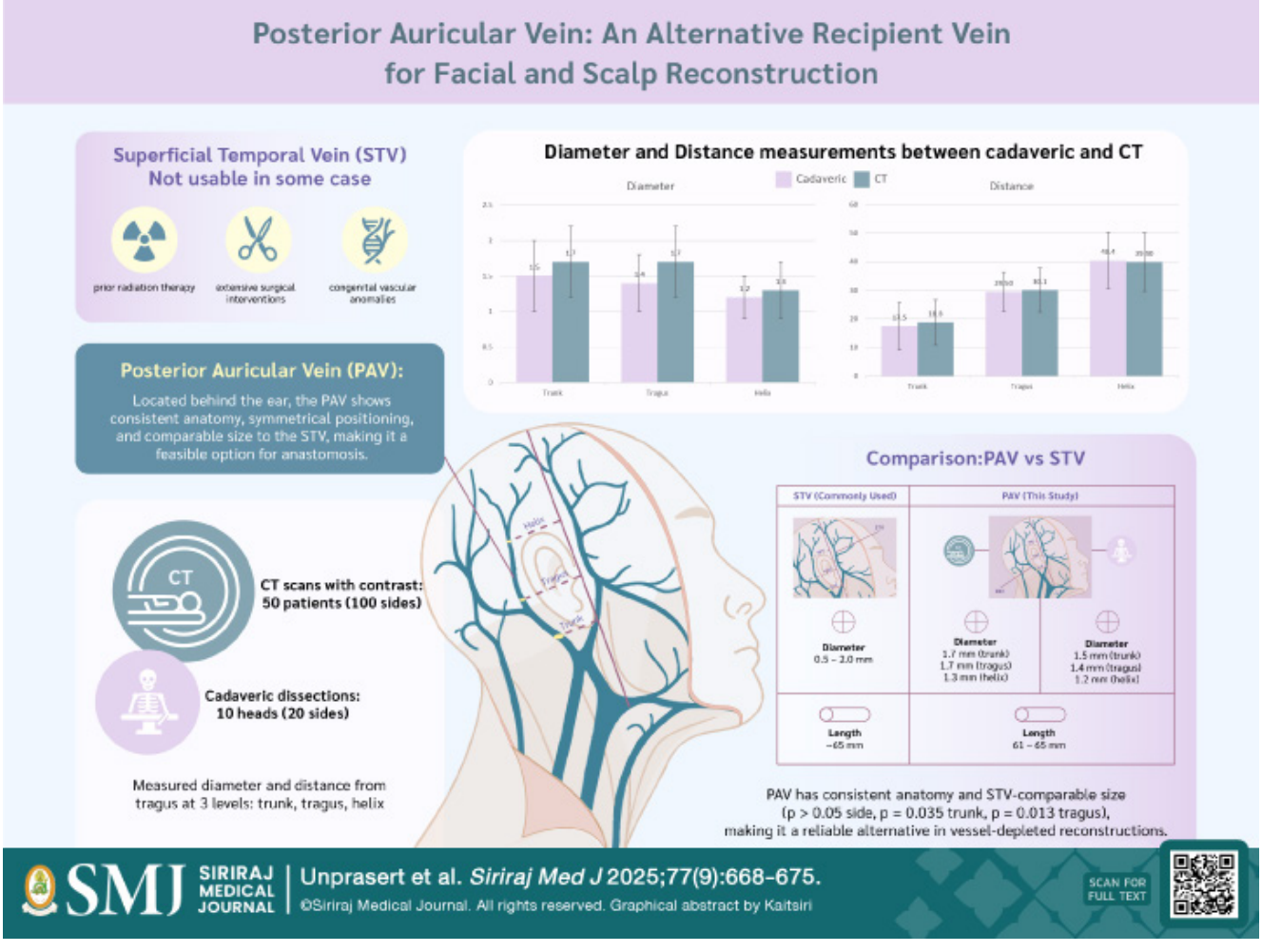

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ABSTRACT

Objective: To determine the diameter and anatomical location of the posterior auricular vein (PAV) and evaluate its suitability as an alternative recipient vein to the superficial temporal vein in microvascular facial and scalp reconstruction.

Materials and Methods: A retrospective study was conducted using 50 contrast-enhanced cranial CT scans (100 sides) and anatomical dissections on 10 fresh cadaveric heads (20 sides) between 2015 and 2019 at Siriraj Hospital, Mahidol University. Measurements of PAV diameter and its distance from the vertical tragus line were recorded at the trunk, tragus, and helix levels. Descriptive statistics and side-to-side comparisons were analyzed using appropriate analytical tools.

Results: CT scans showed mean PAV diameters of 1.74 ± 0.51 mm (trunk), 1.67 ± 0.49 mm (tragus), and 1.33 ± 0.42 mm (helix). Corresponding cadaveric measurements were 1.47 ± 0.48 mm, 1.39 ± 0.41 mm, and 1.16 ± 0.34 mm, respectively. Statistically significant differences were noted at the trunk ($p = 0.035$) and tragus ($p = 0.013$). The ICC values ranged from 0.81 to 0.91. No significant differences in positional measurements were found ($p > 0.05$).

Conclusion: The posterior auricular vein demonstrates consistent anatomical parameters and a diameter comparable to the superficial temporal vein. These findings support its feasibility as a reliable alternative for venous anastomosis in facial and scalp microvascular reconstruction, especially in vessel-depleted cases.

Keywords: Posterior auricular vein; superficial temporal vein; microvascular surgery; cranial computed tomography; cadaveric dissection (Siriraj Med J 2025; 77: 668-675)

INTRODUCTION

Microvascular reconstruction is a vital surgical technique for addressing complex facial and scalp defects. These procedures rely on the precise anastomosis of small-caliber blood vessels to ensure adequate tissue perfusion and long-term flap viability. The success of such operations largely depend on selecting suitable recipient vessels that can support optimal blood inflow and outflow.[1]

Commonly, reliable recipient vessels, such as the superficial temporal vein (STV) are used in facial and scalp reconstructions due to their consistent anatomical location, appropriate diameter, and ease of surgical access.[1,2] However, the availability of these vessels may be severely compromised by prior radiation therapy, extensive surgical interventions, or congenital vascular anomalies — factors that present major clinical challenges for reconstructive surgeons.[3,4] In such cases, identifying alternative recipient veins becomes essential to achieving successful reconstruction outcomes.[5,6]

The posterior auricular vein (PAV) is an anatomically promising yet clinically underexplored candidate located superficially behind the auricle, the PAV offers predictable anatomical features, convenient surgical access, and a suitable size for microsurgical anastomosis.[7-9] Despite these advantageous characteristics, the PAV has been rarely investigated or utilized in reconstructive surgery, and existing literature on its feasibility and clinical outcomes remains limited.[8,10,11]

Cadaveric dissection remains a gold standard for anatomical validation, and several previous studies have exemplified its utility across various anatomical regions and clinical contexts.[12–14]

To address this critical clinical and academic gap, our study comprehensively evaluates the dimensions and anatomical positioning of the PAV using advanced contrast-enhanced computed tomography (CT) imaging, validated by precise anatomical dissections in cadaveric specimens. By providing detailed, clinically relevant anatomical data, this research aims to establish the PAV as a reliable alternative recipient vein. Such validation has the potential to enhance surgical flexibility, improve reconstructive outcomes, and significantly inform microvascular reconstruction planning, particularly in challenging clinical scenarios involving vessel depletion.[3,4,15]

MATERIALS AND METHODS

This study was designed to assess the posterior auricular vein as an alternative recipient vessel for microvascular facial reconstruction. The research included both living patients and cadaveric specimens, all over the age of 15 years. Two primary approaches were employed for data collection: contrast-enhanced cranial computed tomography imaging in living subjects and anatomical dissection in cadaveric specimens. (Fig 1).

In the imaging cohort, 50 patients underwent contrast-enhanced cranial CT scans using one of three multidetector CT scanners: Discovery CT 750HD (GE

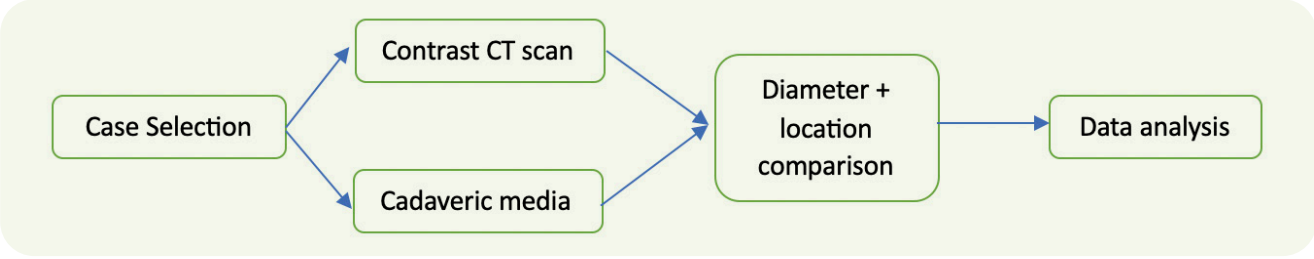

Fig 1. Schematic workflow of the study methodology, including case selection, contrast-enhanced CT scanning, cadaveric dissection, and data analysis.

healthcare, Chicago, IL), Revolution CT (GE Healthcare, Thailand), or Revolution Apex (GE Healthcare, Thailand), with all following standardized contrast protocols. The contrast-enhanced CT scans extended from the sternal notch to the sella and were performed with a tube voltage of 120kVp. Iodinated contrast medium (70 mL) was infused via the dorsal arch of the hand at a rate of 3ml/s, followed by a 20 mL saline flush. The delayed imaging phase was acquired 60 seconds after contrast injection, with a slice thickness of 1.25 mm. Posterior auricular vein diameters were measured on three-dimensional reconstructed images at three anatomically significant landmarks: the trunk, tragus, and superior border of the helix, bilaterally. These landmarks were strategically chosen for their clear anatomical definition, surgical relevance, and ease of intraoperative identification, making the data directly applicable to reconstructive surgeons. (Fig 2). All CT measurements were performed independently by one radiologist and two surgeons blinded to each other's assessments. Interobserver agreement was calculated using the Intraclass Correlation Coefficient (ICC).

In the anatomical dissection arm, 10 fresh adult cadaveric heads were used. The cadaveric specimens were thawed and vascular structures were carefully injected with a silicone-based contrast medium (Silicone RA320 (Rungart, Bangkok)), diluted in solvent (Por Dee Frame, Bangkok) at a 3:7 weight ratio. An incision was made along the posterior border of the mandibular angle to provide optimal access to the vessels. The silicone mixture was injected at a physiologic rate, allowing for detailed visualization of both venous and arterial structures. After preparation, the posterior auricular vein was dissected and measured at the same three anatomical landmarks used in the CT cohort: trunk, tragus, and helix. Both diameter and positional measurements were recorded for each specimen.

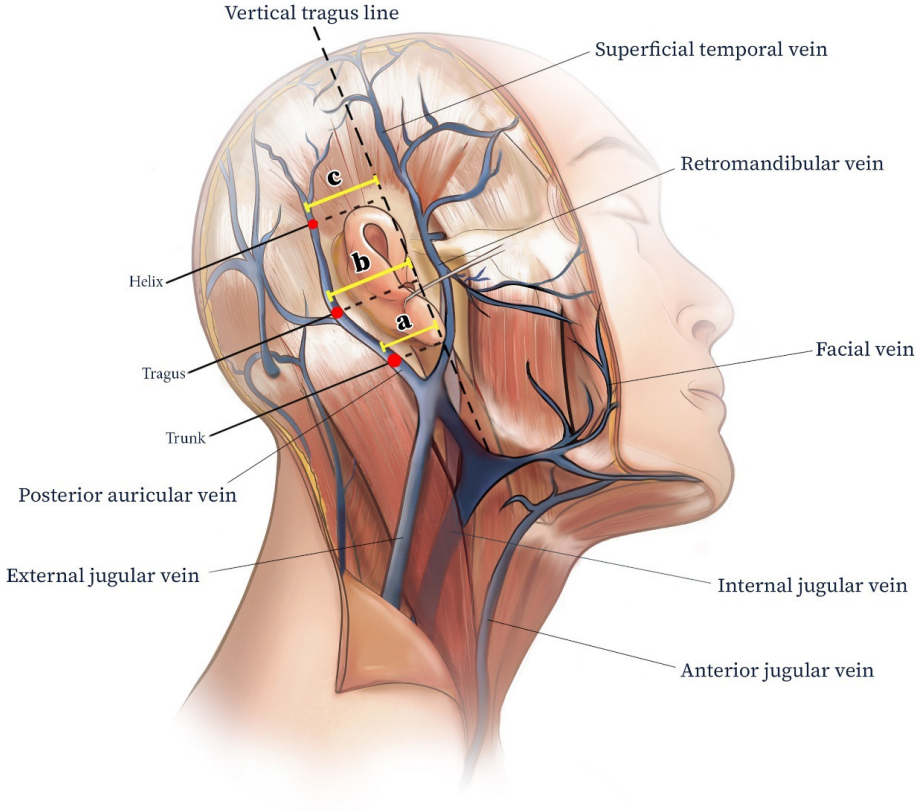

Fig 2. Anatomy of the neck veins showing the External jugular vein (EJV), Internal jugular vein (IJV), Posterior auricular vein (PAV) and other branches including the Superficial temporal vein (STV), Retromandibular vein (RMV), Facial vein (FV) and Anterior jugular vein (AJV). Red dots indicate the measurement points for vein diameter at the trunk, tragus, and helix, measured horizontally at the level of the auricle. The distances of the posterior auricular vein at these levels are labeled as (a), (b), (c) respectively. These distances are measured from the confluence point defined by a line perpendicular to the vertical tragus line and a horizontal line drawn from each of the trunk, tragus and helix.

Statistical analyses

Following data collection, descriptive statistical methods were used to analyze the results. Mean values, ranges, and standard deviations were calculated for both the diameter and location of each anatomical point. Comparisons were made between the CT and cadaveric groups, as well as between left and right sides, to assess anatomical symmetry and validate the findings. Additionally, measurements of the posterior auricular vein were compared with published dimensions of the commonly used superficial temporal vein to evaluate its suitability as a recipient vessel in microvascular reconstruction. Normality was assessed, and group comparisons were conducted using independent t-tests or Mann-Whitney U tests. For normally distributed data, independent t-tests were used. On the other hand, for non-normal distributions, the Mann-Whitney U test was applied. Mean differences and 95% confidence intervals were reported to evaluate the magnitude of anatomical differences between CT and cadaveric groups. All statistical analyses were conducted using SPSS Statistics version 20.0 (SPSS, Inc., Chicago, IL, USA).

This methodological approach was designed to establish a reliable anatomical basis for considering the posterior auricular vein as a potential recipient vein in patients with depleted neck vessels, especially in cases where the superficial temporal vein is unavailable or unsuitable.

RESULTS

The study included 50 patients who underwent contrast-enhanced cranial CT scans and 10 fresh adult cadaveric heads, yielding comprehensive bilateral data from both living and cadaveric subjects. The sample comprised both genders, with 34 males (68%) and 16 females (32%), with a combined mean age of 66.57 ± 10.30 years, ensuring a representative anatomical assessment.

Measurements obtained from the contrast-enhanced cranial CT scans showed that the mean diameter of the posterior auricular vein was 1.7 mm (range: 0.7–2.9 mm) at the trunk, 1.7 mm (range: 0.7–2.8 mm) at the tragus, and 1.3 mm (range: 0.6–2.2 mm) at the helix. There were no statistically significant differences between the right and left sides at any anatomical level ($p > 0.05$) (Table 1). Similarly, the cadaveric dissection group demonstrated mean diameters of 1.5 mm (range: 0.6–2.6 mm) at the trunk, 1.4 mm (range: 0.7–2.2 mm) at the tragus, and 1.2 mm (range: 0.6–1.8 mm) at the helix. Statistical analysis revealed no significant differences between the right and left sides in this group. (Table 2)

TABLE 1. Mean diameters of the posterior auricular vein measured by CT scans (N=100).

CT (N=100)	Right (mm)		Left (mm)		All (mm)		P-value
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Right vs Left
Trunk Diameter	1.8±0.6	0.72.9	1.7±0.5	0.72.9	1.7±0.5	0.72.9	0.207
Tragus Diameter	1.7±0.5	0.82.8	1.6±0.4	0.72.5	1.7±0.5	0.82.8	0.085
Helix Diameter	1.3±0.4	0.62.2	1.4±0.4	0.72.1	1.3±0.4	0.62.2	0.305

TABLE 2. Mean diameters of the posterior auricular vein measured by cadaveric dissections (N=20).

Cadaveric (N=20)	Right (mm)		Left (mm)		All (mm)		P-value
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Right vs Left
Trunk Diameter	1.4±0.4	0.62.2	1.6±0.5	0.62.6	1.5±0.5	0.62.6	0.441
Tragus Diameter	1.3±0.3	0.71.7	1.5±0.4	0.82.2	1.4±0.4	0.72.2	0.498
Helix Diameter	1.1±0.3	0.61.6	1.2±0.3	0.61.8	1.2±0.3	0.61.8	0.505

Regarding anatomical positioning, the mean distance from the vertical tragus line to the posterior auricular vein, as measured on CT, was 18.8 mm at the trunk, 30.1 mm at the tragus, and 39.9 mm at the helix. (Table 3). Cadaveric measurements were comparable, with mean distances of 17.5 mm, 29.5 mm, and 40.4 mm at the trunk, tragus, and helix, respectively. (Table 4) (Fig 2) These positional findings were consistent across both sides and study groups (CT and cadaveric groups), with no statistically significant differences noted ($p > 0.05$). Comparative analysis between the CT and cadaveric cohorts revealed statistically significant differences in diameters at the trunk (right side, $p=0.030$; overall, $p=0.035$) and at the tragus (right side, $p=0.013$; overall, $p=0.013$), with consistently larger diameters observed in the CT group (Fig 3). No significant differences were observed in helix diameters or in anatomical distances at any landmark between the two methods (all $p > 0.05$) (Table 5). The observed discrepancies in trunk and tragus diameters may be attributed to post-mortem tissue changes in cadaveric specimens or limitations in CT imaging resolution.

Importantly, the measured diameters and harvestable lengths of the PAV closely matched those of the commonly used superficial temporal vein (STV), which is typically reported to have a diameter ranging from 0.5–2.0 mm and a harvestable length of approximately 65 mm. In our study, the harvestable length of the PAV reached up to 65 mm on CT imaging and 61 mm on cadaveric dissection, further supporting its clinical viability.

In summary, the posterior auricular vein demonstrates consistent anatomical dimensions and positioning, comparable to the widely used superficial temporal vein. These findings highlight its potential as a reliable alternative recipient vein for facial and scalp microvascular reconstruction procedures.

DISCUSSION

The study presents a comprehensive anatomical analysis of the posterior auricular vein, evaluating its diameter and positioning using both contrast-enhanced cranial computed tomography and cadaveric dissection. The primary objective was to assess the feasibility of the PAV as an alternative venous recipient for microvascular facial reconstruction, particularly in cases where the commonly used superficial temporal vein (STV) is unavailable due to prior surgery, radiation therapy, or anatomical variation.

Our findings demonstrate that the mean diameter of the PAV at three anatomical points (trunk, tragus,

TABLE 3. Mean distances of the posterior auricular vein measured by CT scans (N=100).

CT (N=100)	Right (mm)		Left (mm)		All (mm)		P-value
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Right vs Left
Trunk Distance	19.1±8.0	7.039.0	18.6±8.0	5.035.0	18.8±7.9	5.054.0	0.786
Tragus Diameter	31.0±7.8	15.054.0	29.2±7.4	15.045.0	30.1±7.7	15.054.0	0.263
Helix Diameter	40.0±10.1	20.065.0	39.8±10.3	20.060.0	39.9±10.2	20.065.0	0.936

TABLE 4. Mean distances of the posterior auricular vein measured by cadaveric dissections (N=20).

Cadaveric (N=20)	Right (mm)		Left (mm)		All (mm)		P-value
	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Right vs Left
Trunk Diameter	18.7±7.6	930	16.2±9.1	533	17.5±8.3	533	0.620
Tragus Diameter	28.9±6.1	2040	30.0±7.9	1944	29.5±6.9	1944	0.773
Helix Diameter	39.7±7.9	2851	41.0±11.9	2561	40.4±9.8	2561	0.819

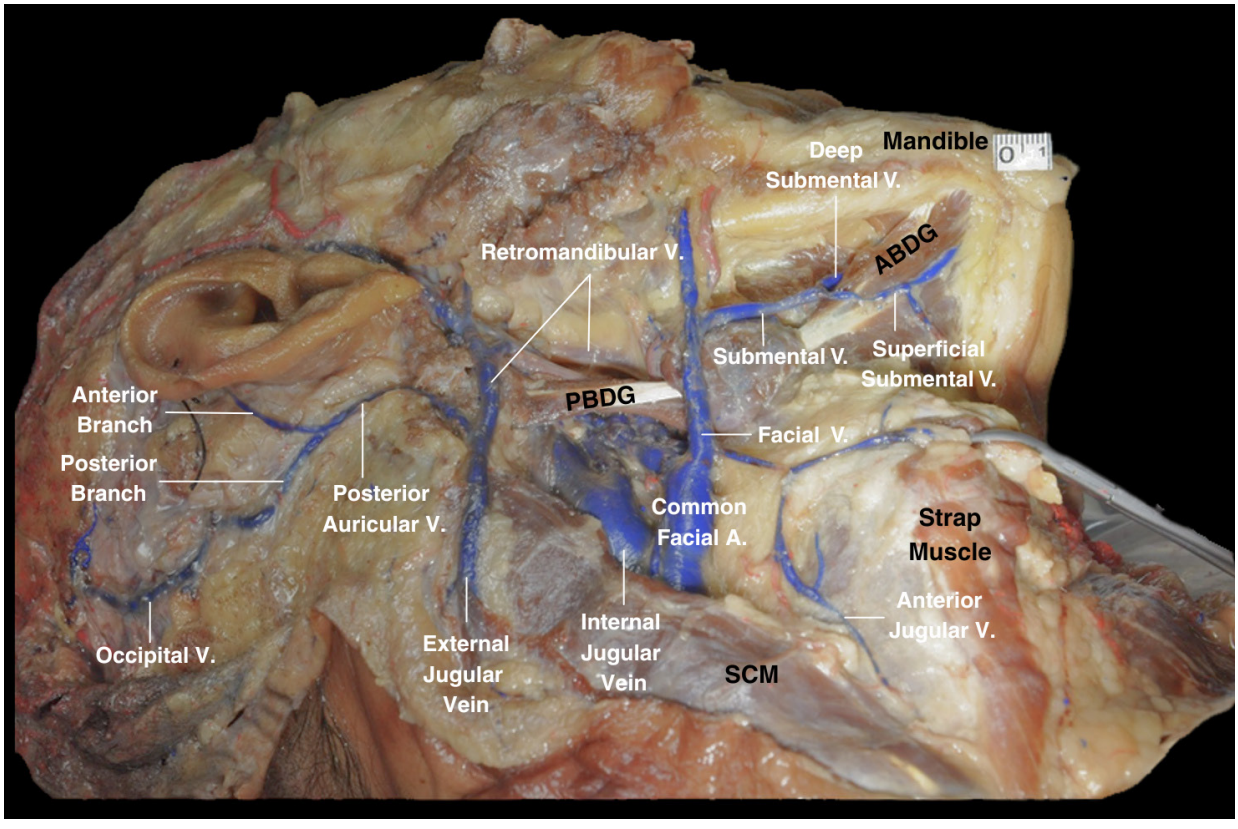

Fig 3. Cadaveric dissection demonstrating the posterior auricular vein (PAV), superficial temporal vein (STV), retromandibular vein (RMV), external jugular vein (EJV), internal jugular vein (IJV), common facial artery (Common Facial A.), occipital vein (Occipital V.), anterior branch (Anterior Branch), posterior branch (Posterior Branch), submental vein (Submental V.), deep submental vein (Deep Submental V.), superficial submental vein (Superficial Submental V.), anterior jugular vein (Anterior Jugular V.), strap muscle (Strap Muscle), mandible, and sternocleidomastoid muscle (SCM). PBDG and ABDG refer to specific labeled anatomic structures.

TABLE 5. Comparisons of diameter and distance measurements between cadaveric and CT groups.

		Cadaveric (N=20)			CT (N=100)			P-value		
		Right	Left	All	Right	Left	All	Right	Left	All
Diameter	Trunk	1.4±0.4	1.6±0.5	1.5±0.5	1.8±0.6	1.7±0.5	1.7±0.5	0.030	0.487	0.035
	Tragus	1.3±0.3	1.5±0.4	1.4±0.4	1.7±0.5	1.6±0.4	1.7±0.5	0.013	0.363	0.013
	Helix	1.1±0.3	1.2±0.3	1.2±0.3	1.3±0.4	1.4±0.4	1.3±0.4	0.201	0.179	0.063
Distance	Trunk	18.7±7.6	16.2±9.1	17.5±8.3	19.5±8.0	18.6±8.0	18.8±7.9	0.896	0.396	0.479
	Tragus	28.9±6.1	30.0±7.9	29.5±6.9	31.0±8.7	29.2±7.4	30.1±7.7	0.423	0.771	0.713
	Helix	39.7±7.9	41.0±11.9	40.4±9.8	40.0±10.1	39.8±10.3	39.9±10.2	0.934	0.749	0.856

and helix), are closely comparable to those of the STV. Specifically, CT imaging revealed mean PAV diameters of 1.7 mm at both the trunk and tragus, and 1.3 mm at the helix. Cadaveric dissection yielded slightly smaller but consistent values: 1.5 mm (trunk), 1.4 mm (tragus), and 1.2 mm (helix), respectively. These results align with previously reported diameter range of the STV, which typically ranges from 0.5 to 2.0 mm. Furthermore, the harvestable length of the PAV reached up to 65 mm on CT and 61 mm in cadaveric specimens, closely matching the average STV length reported in literature (approximately 65 mm).[16]

The bilateral symmetry of PAV measurements observed in both living subjects and cadaveric specimens reinforce its reliability as a recipient vessel, regardless of the side chosen for anastomosis. This consistency is notable given the anatomical variability often encountered with STV and its arterial relationships in the pre-auricular region, which can complicate vessel selection.[1,2,16,17] Our findings suggest that the posterior auricular vein can be confidently considered a suitable alternative in microsurgical reconstruction, offering both anatomical consistency and dimensions comparable to the superficial temporal vein. This supports previous clinical evidence, such as the report by Kim et al, in which a successful anastomosis of a free flap was performed using the PAV in a patient lacking superficial temporal vessels[8], further highlighting its viability in vessel-depleted scenarios. These findings also align with prior cadaver-based anatomical research from Siriraj Hospital, which has consistently demonstrated the value of combining morphometric analysis with clinical relevance, particularly in regions with complex vascular architecture.[12-14]

Although statistically significant differences in diameter were observed between CT and cadaveric measurements, especially at the trunk and tragus on the right side, these discrepancies may be attributed to the small sample size of cadaveric specimens, postmortem shrinkage and stiffness, as well as intrinsic limitations in CT resolution for fine vascular structures. These limitations are consistent with previous research indicating that cadaveric dissection remains the gold standard for anatomical measurements, while CT and MRI, though valuable, may yield less precise measurements.[18,19] Expanding sample sizes in future studies will help address statistical bias and confirm our findings.

The clinical relevance of the PAV as an alternative to the STV is underscored by the increasing frequency of complex reconstructions in the vessel-depleted neck.[3–5] The fragile nature of venous structures, compounded by prior interventions or radiation therapy, often limits the availability of suitable recipient veins. Given its anatomical proximity, comparable size to the STV, and consistent drainage patterns[2,20,21], the PAV stands out as a valuable backup option, potentially improving outcomes in cases where conventional recipient veins are unavailable.

This study contributes to the growing body of literature aimed at optimizing reconstructive strategies in head and neck microsurgery. By providing detailed morphometric data and supporting the feasibility of using the PAV as a recipient vein, we offer practical guidance for surgical planning, particularly in challenging clinical scenarios. Notably, these findings support the routine consideration of the PAV in microvascular facial reconstruction, enhancing both versatility and safety in vessel selection.

Limitations of this study include the relatively small cadaveric sample size and the potential for measurement bias inherent in imaging-based assessments. Future investigations involving larger cohorts and improved imaging protocols will be useful in validating these results and further elucidating the anatomical understanding of this promising vessel.

CONCLUSIONS

The posterior auricular vein exhibits consistent diameter and anatomical positioning comparable to the superficial temporal vein. These findings support its clinical feasibility as an alternative recipient vein in microvascular facial and scalp reconstruction, particularly in vessel-depleted cases.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare no conflicts of interest.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization and methodology, P.O., P.P., and N.Y.; Investigation, P.O., P.P., and C.S.; Formal analysis, P.O., P.P., S.A. and N.Y. ; Visualization and writing – original draft, P.O., S.A., C.S., P.P. and N.Y.; Writing – review and editing, S.A. and N.Y.; Funding acquisition, N.Y.; Supervision, S.K. and N.Y.; Project administration, N.Y.; All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

During the preparation of this manuscript, the authors used ChatGPT to improve readability and grammar. All content was subsequently reviewed and edited by the authors, who take full responsibility for the final version.

REFERENCES

1. Hansen SL, Foster RD, Dosanjh AS, Mathes SJ, Hoffman WY, Leon P. Superficial temporal artery and vein as recipient vessels for facial and scalp microsurgical reconstruction. Plast Reconstr Surg. 2007;120(7):1879–84.
2. Delgove L, Lebeau J, Raphaël B, Champetier J. Drainage of the scalp by the superficial temporal vein: surgical implications. Surg Radiol Anat. 1991;13(4):277–82.
3. Kushida-Contreras BH, Manrique OJ, Gaxiola-García MA. Head and neck reconstruction of the vessel-depleted neck: a systematic review of the literature. Ann Surg Oncol. 2021;28(5):2882–95.
4. Fichter AM, Wolff KD. Reconstructive options in the vessel-depleted neck: past, present and future strategies. Innovations and New Developments in Craniomaxillofacial Reconstruction. 2021.p.211–26.
5. Prince AD, Broderick MT, Neal MEH, Spector ME. Head and neck reconstruction in the vessel depleted neck. Front Oral Maxillofac Med. 2020;2:13.
6. Chopra K, Williams N, van Zyl A. Adjunctive application of Integra® in free-flap surgery for scalp defects. Int Med Case Rep J. 2022;15:483–91.
7. Bechmann S, Rahman S, Kashyap V. Anatomy, head and neck, external jugular veins. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2019.
8. Kim DJ, Park H. Use of the frontal branch of the superficial temporal artery and the postauricular vein to overcome anatomic variations of superficial temporal vessels in scalp reconstruction with free tissue transfer: a case report. Arch Craniofac Surg. 2024;25(2):145–9.
9. Lassus P, Lindford A. The temporal artery posterior auricular skin flap for head and neck reconstruction. Head Neck. 2017;39(12):2434–41.
10. Zhang YZ, Li YL, Yang C, Fang S, Fan H, Xing X. Reconstruction of the postauricular defects using retroauricular artery perforator-based island flaps: Anatomical study and clinical report. Medicine (Baltimore). 2016;95(37):e4853.
11. Pierrefeu A, Bonnafous S, Gagnieur P, Daurade M. Posterior auricular artery helix root free flap—part II: clinical application. Int J Oral Maxillofac Surg. 2022;51(5):632-6.
12. Taweepraditpol S, Prapassorn P, Yongsuvimol M, Kotistienkul B, Piyaman P, Wasinrat J, et al. Surgical anatomy of the lateral thoracic artery and its perforators: A computed tomographic angiography and cadaveric dissection study. Siriraj Med J. 2024;76(12):876–83.
13. Ratanayotha A, Mon Oo E. Chronicle of anatomical education in Thailand: Experiences at Siriraj Medical School. Siriraj Med J. 2022;74(7):463–71.
14. Turbpaiboon C, Sunan R, Rodma D, Promtang S, Pandeya A, Ratanalekha R, et al. Deep peroneal nerve: Orientation and branching at the ankle and proximal part of the foot. Siriraj Med J. 2022;74(7):440–7.
15. Leedy JE, Janis JE, Rohrich RJ. Reconstruction of acquired scalp defects: an algorithmic approach. Plast Reconstr Surg. 2005;116(4):54e–72e.
16. Nokovitch L, Devauchelle B, Peyrachon B, Vacher C, Deneuve S. Caractéristiques anatomiques du système veineux temporal superficiel et implications en microchirurgie. Ann Chir Plast Esthet. 2021;66(3):250–6.
17. Chen JT, Sanchez R, Garg R, Poore S, Siebert JW. Helpful hints for the superficial temporal artery and vein as recipient vessels. Plast Reconstr Surg. 2017;139(3):818e–20e.
18. Paech D, Kloprie K, Nawrotzki R, Schlemmer HP, Giesel FL, Kirsch J, et al. Strengths and weaknesses of non-enhanced and contrast-enhanced cadaver computed tomography scans in the teaching of gross anatomy in an integrated curriculum. Anat Sci Educ. 2022;15(1):143–54.
19. Schramek GGR, Stoevesandt D, Reising A, Kielstein JT, Hiss M, Kielstein H. Imaging in anatomy: a comparison of imaging techniques in embalmed human cadavers. BMC Med Educ. 2013;13:1–7.
20. Imanishi N, Nakajima H, Minabe T, Chang H, Aiso S. Venous drainage architecture of the temporal and parietal regions: anatomy of the superficial temporal artery and vein. Plast Reconstr Surg. 2002;109(6):2197–203.
21. Onishi S, Imanishi N, Yoshimura Y, Inoue Y, Sakamoto Y, Chang H, et al. Venous drainage of the face. J Plast Reconstr Aesthet Surg. 2017;70(3):433–40.