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Journal of The Cardiovascular Thoracic Anaesthesia and Intensive Care Society

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Journal of The Cardiovascular Thoracic Anaesthesia and Intensive Care Society

ABOUT

The Journal of Cardio-Vascular-Thoracic Anaesthesia and Intensive Care Society (GKDAYB Journal) is an official scientific journal of Cardio-Vascular-Thoracic Anaesthesia and Intensive Care Society journal (GKDA-YBD).

The journal publishes clinical and experimental studies, case reports, editorial letters, review articles and reports of scientific meetings related to fields of Thoracic, Cardiovascular Anesthesia and Intensive Care the both in English, Review articles written upon request of the editor are not accepted.

The journal is published every three months namely in March, June, September and December. One volume is completed after publication of 4 issues (one year). GKDAYB is an open access, free and peer-reviewed journal and all published content is freely available at www.gkdaybd.org Printed copies are distributed to members of the Cardio-Vascular-Thoracic Anaesthesia and Intensive Care Society free of charge.

GKDAYB Journal is included in Excerpta Medica / Electronic Publ., EBSCO Publishing Inc. Database; Turkish Medline National Health Sciences Per iodicals Database, Turkish Citation Index and ULAKBIM National Database (from 2016).

Scopus coverage (2003-2017). Discontinued.

AIMS & SCOPE

The purpose of the journal; to publish clinical and experimental studies including new developments related to anesthesia and intensive care of the chest, heart and vascular surgery.

YAYIN KURULU

The board ensure the determination and implementation of the publication policy of the journal. It supposed toformed from editor in chief, assistant editors and academicians who will contribute to the journal policy and the academic accumulation of the journal, and how journal should be noted up-to-date. If its possible, people from different institutions should take part.

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PUBLICATION POLICIES

This guideline has been prepared by Kare Media, by examining the leading national and international institutions of the publishing sector, and it has been found appropriate and adopted by the editorial board of the journal. It is recommended that all researchers who will send their studies to the journal should examine this guide carefully. The resources and international authorities used during the preparation proces of these policies are indicated at the end of the guideline.

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Creative Commons
COPE (Committee on Publication Ethics)
DOAJ Principles Of Transparency And Best Practice In Scholarly Publishing, Version 3
Education and Science Journal Publication Policies
ICMJE (International Committee Of Medical Journal Editors)
COHE Scientific Research and Publication Ethics Directive

OPEN ACCESS POLİCY

As a publisher that is aware of the fact that information should be easily accessible for the advancement of scientific studies Kare Media supports the open access initiative declared in Budapest Open Access Initiative which states that the peer-reviewed journal literature should be open access, and offers all the published articles free of charge in an environment where everyone can read and download. The term "open access" in this declaration means that" by means of internet, scientific literature can be accessed, read, recorded, copied, printed, scanned, linked to full text, indexed, transferred as data to the software, and used for all legal purposes without the financial, legal and technical barriers

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These open access policies accepted on September 12, 2012, and also adopted by our editorial board are also accessible at http://www.budapestopenaccessinitiative.org/boai-10-translations/turkish-translation.

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Open access is an approach that reinforces interdisciplinary development and encourages cooperation between different disciplines. For this reason, The Journal of Cardio-Vascular-Thoracic Anaesthesia and Intensive Care Society contributes to its field by offering more access to its articles and a more transparent review process.

ETİK POLİTİKASI

It is targeted that all parties participating in the creation of a scientific study (author, editor, reviewer, publisher and reader) contribute to the proper progress of science. Compliance with scientific ethical principles is important in the scientific studies prepared in accordance with this target. Kare Media Inc. adopted the ethical principles based on the directive prepared by the Committee on Publication Ethics (COPE) and recommended its adoption by all individuals contributing in the creation of a scientific work. Some items of this directive are mentioned below.

Ethical Responsibilities of the Authors

To ensure that the data related to the study is correct, to keep the records of the study regularly and to provide access to these data upon a possible request.

To ensure that the article he/she submitted is not published or accepted elsewhere.

If the content submitted by the author matches the already published or presented content, to accept and quote this conflict and, when necessary, to provide the editor with a copy of any work that may have similar content related to his / her work, to obtain permission to reproduce, and use any content from other sources, and cite it as a reference.

To ensure that all studies involving human or animal subjects comply with national and international laws and guidelines (eg WMA Helsinki Declaration, NIH Policy on the Use of Laboratory Animals, EU Directive on the Use of Animals) to approve that necessary approvals have been obtained, to respect subject privacy, to indicate the relevant ethics committee approvals and research details in "Materials and Methods" section of the study.

In case of any conflict of interest, when he / she finds an ethical violation related to his / her article, he / she will share it with the editor and publisher, and publish a statement of error, addendum, indemnity notice or withdraw the work if deemed it necessary.

Ethical Duties and Responsibilities of the Editors

Acting in a balanced, objective and fair manner while performing their duties without any discrimination based on gender, religious or political beliefs, ethnic or geographical origin of the authors.

To evaluate the work submitted to the journal according to its content without showing any privilege to any author.

To take necessary measures to prevent potential conflicts of interest and to evaluate existing statements, if any.

To deal with sponsored works or special studies in the same way as other studies,

In case of complaints related to violation of ethics, to enforce necessary procedures by adhering to the policies and procedures of the journal. To give the authors an opportunity to respond to the complaint, and without refraining from imposing the necessary sanctions, regardless of the identity of the owner of the work To reject the study if it does not meet the purpose and scope of the journal.

Ethical Responsibilities of the Reviewers

In order to contribute to the editor's decision-making process, the manuscript should be scrutinized in a timely fashion and reviews should only accept the critical evaluation of the study of his/her expertise.

The assessment should be done in an objective manner only in relation to the content of the study. The study should be evaluated without considering religious, political and economic interests.

To make suggestions to help improve the quality of the article to be published and to critically review the study. To communicate his/her comments to the author in a constructive and gentle language.

To protect the confidentiality of the information provided by the editor and the author, to destroy the work after the evaluation process in accordance with the principle of confidentiality, to report to the editor if there is anything contrary to the blind review process and not to evaluate this study.

To be cognizant of potential conflicts of interest (financial, institutional, collaborative, or other relationships between the author and the author), and, if necessary, to alert the editor to withdraw his or her assistance for this article.

Ethical Responsibilities of the Publisher

Among the parties involved in a creation of a scientific study, the publisher should act within all these ethical principles.

In addition to these, the publisher is obliged to use its communication power without any individual interest and to direct the target audience correctly.

It protects the ownership and copyright of each work published in its journals/books and undertakes the task of archiving every published work.

People should not hesitate to get contact with the publisher when they encounter an unethical situation.

Some of the actions considered to be against scientific research and publication ethics

- Plagiarism: To adopt the original ideas, methods, data or works of others partially or wholly without referencing them in compliance with scientific rules,
- Fraud: to use data that is not actually present or falsified in scientific research
- Distortion: Distorting the research records or data obtained, demonstrating unused devices or materials as if they were used in the research, and distorting or shaping the results of research in the interests of the people and organizations that sponsored the study;
- Republication: To present duplicates as separate publications in academic appointments and elevations
- Slicing: To present the results of a research as separate publications in academic appointments and upgrades by disseminating and publishing the results of a research in a way that disrupts the integrity of the research and submit them as separate publications more than once;
- Unfair authorship: to include people who are not active contributors or not to include those who are contributing to the study, to change the ranking of the authors inappropriately without any justification and, to remove the names of those who offered their active contributions in t the previous editions, to include their names among the writers by using their influence even though they did not actively contributed to the work
- Not specifying the people, institutions or organizations that support the publications realized as a result of the researches carried out with their support, and contributions,
- To use the thesis or studies which have not been submitted yet or have not been accepted as a source without the permission of the owner,
- Failure to comply with ethical rules in human and animal researches, not to respect patient rights in its publications, to harm animal health and ecological balance, to refrain from obtaining necessary permissions,
- To misuse resources, places, facilities and devices provided for scientific research,
- To make false or misleading statements regarding scientific research and publications in academic appointments and elevations.

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At submission, the journal should require authors to disclose whether they used artificial intelligence (AI)-assisted technologies (such as Large Language Models [LLMs], chatbots, or image creators) in the production of submitted work. Authors who use such technology should describe, in both the cover letter and the submitted work, how they used it. Chatbots (such as ChatGPT) should not be listed as authors because they cannot be responsible for the accuracy, integrity, and originality of the work, and these responsibilities are required for authorship. Therefore, humans are responsible for any submitted material that included the use of AI-assisted technologies. Authors should carefully review and edit the result because AI can generate authoritative-sounding output that can be incorrect, incomplete, or biased. Authors should not list AI and AIassisted technologies as an author or co-author, nor cite AI as an author. Authors should be able to assert that there is no plagiarism in their paper, including in text and images produced by the AI. Humans must ensure there is appropriate attribution of all quoted material, including full citations.

PLAGIARISM POLICY

Plagiarism (cheating) is a violation of ethics, regardless of whether it is intentional or not. It is a crime and an unacceptable code of conduct as it is unethical to submit, and publish manuscripts imitating other sources, without citing references,. For this reason, due to publication policies Kare Media Co. (hereinafter it will be referred as KARE), for all studies to be published in all of its periodicals, necessitates use of a plagiarism checker.

All studies submitted to our periodicals and passed the evaluation of the reviewers blinded to the studies, are evaluated by us using Turnitin or iThenticate software programs.

In our study, our criterion is not a percentage of matching. An auditng is carried out by a specialized team excluding percentages of matching but considering the parameters, such as identification of matching paragraphs, whether or not citations and references are properly written in accordance with the writing rules of the journal, the places of the matching sentences/paragraphs in the article, and the sources with which they are matched. The prepared plagiarism report is sent to the relevant editor of the study. In consideration of the report, the editorial board may request from the author correction of the errors in the manuscript and sent it again or accept or reject it. The acceptance of the study is on the initiative of the editor.

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Publication processes of the Journal is carried out in accordance with the guidelines of International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Scientific Council of Editorial (CSE), Committee of Publication Ethics (COPE), European Association of Science Editors (EASE) and National Information Standards Organization (NISO).

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Authors who will send a study to our journal should complete the "**Copyright Transfer Form**" document. The author(s) must sign the completed form with a wet signature. The signed form must be scanned and loaded with additional file upload option in successive steps of submission process.

CONFLICT ON INTEREST

Conditions which provide financial or personal benefit bring about a conflict of interest. The reliability of the scientific process and the published articles is directly related to the objective consideration of conflicts of interest during the planning, implementation, writing, evaluation, editing and publication of scientific studies.

Financial relations are the most easily identified conflicts of interest and it is inevitable that they will undermine the credibility of the journal, the authors and the science. These conflicts can be caused by individual relations, academic competition or intellectual approaches. The authors should refrain as much as possible from making agreements with sponsors in the opinion of gaining profit or any other advantage that restrict their ability to access to all data of the study or analyze, interpret, prepare, and publish their articles In order to prevent conflicts of interest, editors should refrain from bringing together those who may have any relationship between them during the evaluation of the studies. The editors, who make the final decision about the articles, should not have any personal, professional or financial ties with any of the issues they are going to decide. Authors should inform the editorial board concerning potential conflicts of interest to ensure that their articles will be evaluated within the framework of ethical principles through an independent assessment process.

Our publication team works devotedly to ensure that the evaluation process is conducted in an impartial manner, taking all these situations into consideration.

You can review the conflict of interest form and the related link to get more detailed information and to declare an conflict of interest.

WRITING GUIDE

Double-Blind Review And Evaluation Process

The decision to publish all articles submitted to the journal belongs to the editor in chief. However, editors shape these decisions in line with the reviewers' recommendations.

The double blind review process is the process of evaluating the work completely anonymously. In this system, only the editor knows each stage. In this system authors do not know who the reviewer is, and the reviewers do not know whose work they are evaluating. Thus, biased evaluation of the work by the reviewers is prevented. In addition, since the author does not know the reviewers, he/she can not possibly get contact with the reviewer, and influence him/her through 'special routes'. From this point of view, the double- blind review process is thought to provide objective evaluation and increase the equal opportunity.

For these reasons, all studies submitted to GKDAYB Journal are subject to double-blind review. At least two reviewers expert in their fields, will evaluate each submitted work. Every effort is spent by the editors for quick evaluation of the articles. The editor is the final decision-making authority in the evaluation processes of all articles.

First Evaluation

The relevant editor or journal secretary examines the work regarding the purpose and scope of the journal, its conformity to the rules of writing, and its English and Turkish language proficiency. As a result of this assessment, the manuscripts which do not comply with the publication rules and the publication policy of the journal are returned to the responsible author.

Preliminary Evaluation Process

In the pre-evaluation process; the study that left a positive impression on the editor is directed to the field editors. Field editors examine summary, introduction, material / method, discussion and conclusion sections of the manuscript as well as its scientific, and formal conformity to the writing rules of the journal. As a result of this review, manuscripts which are found suitable are taken into the process of reviewers' evaluation.

Reviewers' Evaluation Process

According to the content of the manuscript, at least two expert reviewers who had current studies in the relevant field are determined. Suggestions of the field editor regarding the selection of reviewers are appraised by the chief editor, and reviewers are assigned for the assessments of the manuscripts. The reviewers evaluate the study and prepare a report.

Reports of the Reviewers

The reviewers evaluate the objective, material / method, results and discussion sections of the study, and its conformity to scientific principles. The work may be accepted directly, its revision may be requested or rejected. If correction in the manuscript is required, the suggestions coming from the reviewers are communicated to the authors and the authors are asked to revise their work.The results of correction coming from the authors are reexamined by the reviewers and their decisions are reported to the editor. In case of disagreement between the assigned reviewers, the manuscript is sent to a designated third reviewer.

Statistical Analysis

Manuscripts deemed appropriate for publication by the reviewers are sent to the statistical editor. Articles that are approved by the statistical editor are accepted for publication.

Publication Printing Process

Clinical studies or experimental research articles accepted for publication are usually included in the first issue to be published. Case presentations can wait 6-9 months according to the intensity.

CHECKLIST FOR AUTHORS

- Make sure that name of the author (s), information about the institution thank you letter about ethics committee etc. are not included in the study. This issue is important according to the 'double- blind review principle' concerning the evaluation process of your work so that it can be dealt with impartially.
- You should not forget that your study will be subject to plagiarism audit if it is deemed to be adequate and appropriate in terms of the subject and you should avoid making quotations that will be covered by plagiarism when preparing the work.
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last check e-mail sent to you and if there is any neccesary revisions you have to make please send them to us before the journal is published.

MANUSCRIPT PREPARATION

Manuscripts should preferably be written using the Microsoft Word program. The manuscripts should be typed in 12 point Times New Roman characters. Manuscripts should be written double- spaced on one side of the A4 (21x29.7 cm) white paper and throughout the entire manuscript (including headings, abstracts in Turkish and English, main text, references, tables and subtitles) and justified leaving 3-cm margin from both sides. They should be written in accordance with word processor's page layout settings.

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The authors are kindly requested to submit their **ORCID** numbers obtained the website from **www.orcid.org** and indicate them in the relevant area at this stage. Abstract and full text should not containinformation about the individuals and institutions participating in the study.

The files must be loaded in the following order.

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- The file "**References**" should be recorded separately.
- **Tables** should be prepared and written double-spaced on a separate sheet, and the number and title of each table must be written on top of the table. If abbreviations are given in the table, these abbreviations should be written in alphabetical order as subheadigs. . When previously printed or electronically published tables are used, written permission must be obtained from both the author and the publisher, and it must be sent by fax or mail to the editor of the journal.
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- **Copyright transfer form**

Authors must declare that all or part of the material in the manuscript has not been published and is not currently being evaluated elsewhere for publication. Each author must declare that he/she participated in the investigation enough to share the responsibility of its content.

This participation may involve the following issues:

- Creation of concepts and designs of experiments,
- Collection, analysis or expression of the data;
- The preparation of the draft of the mauscript or the review of the scientific content
- Approval of the final format of the manuscript ready for publication
- Ethics committee approval letter
- Original articles and review articles should not exceed 10, case reports 4, letters to editors 1 page (excluding references, tables and graphics).

In the manuscript, the sections and contents of the manuscript should be presented as follows.

Title: A short title should be used whenever possible. The title of the research, and review articles should not exceed 95 characters (each letter, space, and punctuation marks are considered as one character), in case of case reports, letters and presentations of surgical techniques it should not contain more than 80 characters. Abbreviations should not be used in the title. The title should be written in Turkish and English. A short title should be added as a subtitle which should not exceed 40 characters.

Funds and organizations supporting the research should be mentioned here, If the study is planned to be presented in any congress or if it has been presented before, the name, place, and date (day-month-year) of the congress should be written.

The abstracts should not exceed 250 words in the research papers Headings should not be used in summaries (the English translation of the title should be written on the title page). Abstract in Turkish should consist of four subheadings as While abstract in English should include subheadings of Aim, Material and Method, Results, and Conclusion) In case reports and review articles donot contain these sections, and abstracts should not exceed 100 words. English title, and abstract should be. English title and abstract should be word by word translation of the Turksih abstract. Letters to editor, and Editorials do not require abstracts.

Use of abbreviations should be avoided as much as possible in summaries. If absolutely required, abbreviation should be used after its definition is provided in parenthesis at the first mention of the term. Reference should not be used in the abstract.

Key words: In accordance with "Index Medicus Medical Subject Headings (MeSH)" there should be no more than five key words under the summary written both in Turkish and English. Available terms can be used if there is no appropriate term for the "Index Medicus" medical subject headings for the newly entered terms.

Introduction: The general conditions of the study settings, the structure and significance of the problem, the specific objective of the study or research tested in the study or observation should be clearly indicated. The primary and secondary objectives of the work should be clearly stated and the predefined subgroup analyzes should be transferred. Only references related to the topic should be used and the data or results of the presented work should not be included in these references.

Material and Method: The informed consent of the patient and the approval of the ethics committee should be acknowledged. A statement must be added that the informed consent was obtained from each participant in clinical trials. It should be noted in experimental studies that all animals were subjected to a humane treatment in accordance with the Guide for the Care and Use of Laboratory Animals (www.nap.edu/catalog/5140.html).

Definition of optimal working conditions, exclusion criteria and referenced population; the participants in the observational or experimental study must be clearly indicated. Since the relevance of the variables such as age and gender for the purpose of the research is not always obvious, the authors should explain the purpose of using these variables in a research article. The main principles that determine how and why the study is performed using such a method should be clear. References should be shown for established methods, brief descriptions should be given for new methods.

The methods, tools (manufacturer's name and address are written in parentheses) and the operations performed should be described in detail to the extent of interpretation of the results. The initials of the drug names should be in lower case, the pharmacological names of the drugs should be used and at their first mention in the text they should be written in brackets in the following order"Generic name, trade name, and Manufacturing firm ". Example: "midazolam (Dormicum, Roche)". The terms should be written in their explicit forms at their first mention in the text,

and then their abbreviations (if any) should be enclosed in parentheses. Frequently used abbreviations should be used as accustomed (iv, im, po and sc). Units must be used in compliance with the International system of units (SIU (Le Système international d'unités),Examples: mg / kg, mL / kg, mL / kg / min, mL / kg.

Statistical methods should be provided in sufficient detail so that the readers can reach the original data and evaluate the reported results. Findings should be measured as much as possible and the appropriate margin of error and uncertainty (such as confidence intervals) should be indicated. It is important to avoid relying only on the p-values ??of statistical hypothesis measures that are insufficient to convey important information about the dimensions of the effects. P values ??must be given explicitly. Statistical terms, abbreviations and symbols should be defined. In the last paragraph of this section, statistical analyses used, and the values given by the (±) sign after the arithmetic mean or proportion should be indicated.

Results: The findings, tables and visual material obtained in the study should be written in the order of a certain logic so that the most important ones will take precedence in the text. Graphics, tables, illustrations, and figures should be numbered according to the order of their mention in the text, and should be indicated in parentheses in the text. Data contained in the tables and visual materials should not be repeated in the text. Only important observations should be emphasized or summarized. Tables and figures are placed collectively after the last reference at the end of the text. Only the top title of the table, and graphic or the subheading of figures, illustrations, photos are written in their appropriate places in the text.

The numerical results summarized in the Results section should be given not only as derivatives (eg percentages), but with exact numerical values, and the statistical methods used to analyze them should be specified. When scientifically appropriate, data should be analyzed in terms of variables such as age and gender. Tables and pictures should be limited to those necessary to explain and support the discussion expressed in the article. As an alternative to the tables, you should use some kind of graphics on which many entries can be made, and data should not be repeated on graphics and tables. Using non-technical terms such as "random", "explicit", "links" and "example" in the statistics section should be avoided.

Discussion: The results of the study are evaluated by comparing them with the international, and domestic literature. New and important aspects of the study and its outcomes should be emphasized. Data and other information presented in the Introduction and Results sections should not be repeated. In experimental studies, we should briefly summarize the main findings and then analyze explanations with possible mechanisms and compare them with other similar studies. It would be appropriate to comment on the implications of these findings for future researches and clinical practices. The objectives of the work should be correlated with the results. However, unmeasured situations and outcomes that are not adequately reinforced by the data should be avoided. The resulting decision arrived must be stated in the last paragraph of the discussion. If the article does not include appropriate economic data and analysis, no particular comment should be made on economic interests and costs. Claims on an incomplete study should be avoided, new hypotheses must be specified when they are confirmed, and their novelty should be clearly emphasized.

Acknowledgment (if any): If you also want to thank the people who can not fulfill the criteria for authorship involved in fundraising, technical assistance, data collection, supervisor of the research group, writing, or department chiefs who just provided general support, and those providing finance and material support, a brief paragraph can be written under the heading of "Acknowledgement.". Written consent must be obtained from the individuals to be mentioned in the acknowledgment section since they may make a sense of data and conclusions they contributed

Conflict of Interest: The authors are requested to declare any existing commercial association that might potentially have a conflict of interest regarding their articles. (eg employment, direct payments, holding shares, holding, consultancy, patent licensing arrangements, or granting honorarium). All financial resources supporting the study should also be declared as footnotes.

Tables and Charts: Charts can be saved in a single chart file, tables can be placed in one spreadsheet file on each page. Titles, descriptions and footnotes should be placed on each sheet of paper.

The tables reflect the information in a concise and effective way. They also provide information of the desired quality and precision. The fact that the data are given in the tables rather than in the text usually makes it possible to shorten the text. The tables should not be a repetition of the information in the article.

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REVIEW

Nonintubated Anesthesia in Video-assisted Thoracoscopic Surgery

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ABSTRACT

The standard anesthesia method in intubated patients during thoracoscopic surgery is one-lung ventilation (OLV). Accumulated experience in video-assisted thoracoscopic surgery (VATS) has remarkably advanced minimally invasive techniques in thoracic surgeries, a progress that has prompted anesthesiologists to pursue different and alternative methods. The desire to avoid possible general anesthesia side effects, such as intubation-related airway trauma, mechanical ventilation-induced lung damage, residual neuromuscular blockade, and postoperative nausea and vomiting, has led to the introduction of nonintubated anesthesia techniques as an alternative anesthesia method in thoracic surgery. Nonintubated techniques are established to preserve the patient's spontaneous breathing during iatrogenic pneumothorax created by the surgeon during VATS and the atelectasis on the side to be operated on, providing sufficient surgical field of view and allowing successful completion of the surgery. Although this does not compete with continuing traditional thoracic anesthesia, in the future, nonintubated techniques will gain greater acceptance for VATS with appropriate patient selection and increased experience. This article reviews nonintubated anesthesia techniques used in VATS, including their advantages, disadvantages, appropriate patient selection, and complications.

Keywords: Anesthesia, non-intubated, video-assisted thoracoscopic surgery

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Introduction

Traditionally, in thoracoscopic surgeries, one-lung ventilation (OLV) under general anesthesia has been a standard anesthesia method which provides a good safety profile and optimal conditions. The development of uni- and multiportal video-assisted minimally invasive techniques in thoracic surgery has become a springboard for the use of minimally invasive approaches in anesthesia techniques for thoracic surgery to the fore. Since thoracoscopic surgeries conducted under local, regional, or general anesthesia with the aid of subglottic devices in spontaneously breathing patients produce successful results, especially in selected patients, the routine use of these techniques has gained widespread interest.[1,2] Minor and major video-assisted thoracoscopic surgeries (VATS) can be safely performed under regional anesthesia or general anesthesia with subglottic devices in nonintubated spontaneously breathing patients.[3,4] The most important factor limiting their standardization in daily routine use is the risks involved in these anesthesia techniques, especially in major surgical procedures.

In thoracic surgery, non-intubating techniques present challenges and potential advantages for both the anesthetist and the surgeon. This article aimed to review nonintubated anesthesia techniques in VATS.

Brief History

Until the adaptation of an inflatable cuff to an endotracheal tube described by Guedel et al.[5] in 1928, ether or chloroform anesthesia with mask was the most popular anesthesia technique. In the early 1900s, metal endotracheal tubes were designed and later rubber tubes were placed in the absence of laryngoscopy; however, these applications were not widely accepted because these required expertise and skill in blind placement and had to be performed under deep anesthesia. The advent of cuffed tubes was a turning point. Cuffed tubes protected the lungs from gastric aspiration and allowed controlled breathing through the suppression of spontaneous breathing with controlled hyperventilation, while concurrently achieving anesthesia levels deep enough to provide diaphragmatic immobility and apnea.

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In thoracic surgery, cuffed tubes prevented pneumothorax and suppressed the patient's spontaneous breathing; however, contamination from the diseased lung to the healthy lung and the inability to isolate a single lung remained important obstacles in these surgeries. In 1931, Gale et al.[6] described selective one-lung ventilation. In this technique, after patient intubation with a cuffed endotracheal tube, the cuff was advanced to the east of the bronchus of the intact lung and then inflated. Hence, while the healthy lung continued to ventilate, the other lung was deflated. The definition of modern laryngoscopes and the subsequent emergence of the Macintosh laryngoscope blades in 1943, still used today, provided convenience and accuracy in endotracheal tube placement.[7] With the definition of bronchial blocker by Archibald in 1935 and double-lumen tubes (DLT) by Carlens in 1949, great advances in thoracic anesthesia were achieved.[8,9]

Pompeo et al.[10] used epidural anesthesia for solitary pulmonary nodule resection in an awake patient in 2004. In 2007, Al-Abdullatief et al.[11] elucidated that some major surgeries and even lung resections were possible with minimal sedation in a nonintubated patient.

Presently, advancements in VATS allow the use of less invasive anesthesia techniques in these surgeries.

Advantages of Nonintubated Techniques in Vats

Avoiding the risk of possible general anesthesia complications is one of the most significant advantages of non-intubating techniques. In patients undergoing mechanical ventilation under general anesthesia, the incidence of postoperative nausea, vomiting, pulmonary complications, and residual block has been reported as high.[12–14] Difficulty in DLT placement highlights bronchial blocker preference, especially in patients with difficult airways.[15] These difficulties can be overcome with the development and increasing use of flexible bronchoscopies; however, it has been reported that both DLTs and bronchial blockers may be associated with complications, such as sore throat and hoarseness, including very serious airway complications such as arytenoid dislocation and rupture.[16–19] The limited number of studies and meta-analyses comparing non-intubating techniques with traditional intubated OLV techniques in VATS has demonstrated that non-intubated techniques are associated with shorter hospital stays and shorter anesthesia and operation times and thus lower costs, including lesser incidence for hoarseness and sore throat. It has been also demonstrated that non-intubated techniques provide less nursing care and shorten postoperative fasting time.[20–29]

Existing literature has not elucidated whether nonintubating techniques are superior to traditional intubated methods in terms of survival, but it has been reported that they are less efficacious in inflammatory cytokine and lymphocyte responses and stress hormone levels, especially in the postoperative period.[30–32] In patients with comorbidities such as chronic obstructive pulmonary disease who may require intensive care in the postoperative period, nonintubated techniques should be considered as an alternative to conventional OLV.[33]

Disadvantages of Nonintubated Techniques in Vats

Patients can maintain spontaneous breathing during nonintubated VATS. Hypoventilation develops with iatrogenic pneumothorax created during the procedure, which causes pulmonary perfusion decline. Functional residual capacity decreases and hypercapnia develops.[34]

Maintaining airway safety in an emergency is one of the most important problems in nonintubated patients, especially patients in the lateral decubitus position. Although VATS is a safe surgical procedure featuring small incisions, encountering major complications that are difficult to manage is possible.[35] One of the most important complications requiring urgent intervention is bleeding that originates from the pulmonary artery. Emergency thoracotomy may be required for uncontrolled bleeding. In this case, the patient should be intubated in the lateral decubitus position or quickly placed in the supine position. However, where intubation is expected to be difficult, attempting intubation in the lateral decubitus position may render the situation extremely challenging.[36]

Although some conditions such as obesity, emphysema, excessive movement of the diaphragm or mediastinum, or cough render non-intubation techniques difficult to employ, they may not be definite contraindications. Anesthesiologists who will use nonintubated techniques should have experience in this field and the ability to address problems that may occur intraoperatively.

Patient Selection

More often, nonintubated techniques have been used in minor thoracic surgeries involving low-risk patients; however, advancements in technology and increased experience have demonstrated that these techniques are safe and applicable in more complicated procedures for selected and high-risk patients. Their good safety profile has been shown in surgeries such as pulmonary nodule resections,[4,10,37,38] pleural and pericardial effusions,[39] pneumothorax,[40–42] biopsies,[43–45] thymectomy,[46–48] volume reduction surgeries,[29,49] segmentectomy,[50,51] and lobectomy.[26,52,53]

In the past, patients with American Society of Anesthesiologists grades 1–2, body mass index of <30, cardiopulmonary

Table 1. Contraindications for nonintubated techniques

General contraindications
The patient declines
Patients with an ASA score ≥4
Obesity
Anesthesia-related contraindications
Difficult airway expectation
Preoperative FEV_1 <30%
Situations where isolation is necessary to protect the contralateral lung from contamination (acute lung infection, tbc, etc.)
Presence of persistent cough or excessive secretions
Gastric reflux, risk of regurgitation
Presence of phrenic nerve paralysis on the opposite side
Severe cardiopulmonary dysfunction
Hemodynamic instability
Coagulopathy
Neurological disorders (risk of seizures, inability to cooperate), increased intracranial pressure
Presence of hypoxia (PaO_2 <60 mmHg) and/or hypercapnia ($PaCO_2$ >50 mmHg) during resting
Situations resulting in contraindications for regional anesthesia
Surgical-related contraindications
Large pleural adhesions
History of pulmonary resection or ipsilateral thoracic surgery
Pulmonary artery bleeding

ASA: American Society of Anesthesiologists; FEV_1: Forced expiratory volume in one second; PaO_2: Arterial partial pressure of oxygen; $PaCO_2$: Partial carbon dioxide pressure

stability, and no expectation for difficult airway were preferred for nonintubated techniques.[10,28,54] At present, these techniques can be used safely in high-risk patients.[11,45,55–57] Thus far, despite the absence of a definite consensus, similar contraindications for nonintubated techniques are mentioned in the literature.[2,54,58,59] Table 1 summarizes the contraindications for nonintubated techniques. Moreover, in the table, recommendations are presented including what should be considered in the context of surgery and anesthesia team's experience and current patient risk factors.

Anesthesia Management

Preoperative Evaluation

During the preoperative evaluation, patients who are candidates for nonintubated techniques should be educated regarding the surgical procedure to be conducted and the anesthesia method to be employed. Particularly where regional anesthesia techniques are utilized, patients should be warned of the discomforts that may result from staying in the lateral position and the temporary respiratory problems that may occur during iatrogenic pneumothorax.

As premedications, antagonizable agents should be selected. Benzodiazepines may be an optimal option, especially since they can be antagonized with flumazenil to eliminate cooperation disorder and hypoventilation that may occur prior to and during the procedure. It has been reported that complementary techniques such as hypnosis decrease preoperative anxiety and present as an alternative premedication methods for respiratory depression prevention secondary to pharmacological agents.[60,61]

Intraoperative Monitoring

Intraoperative monitoring may differ in accordance with the patient's existing comorbidities and surgical procedure. Routine monitoring should include an electrocardiogram (ECG) with a minimum of three channels, pulse oximetry, and noninvasive blood pressure monitoring (depending on the patient's condition, invasive blood pressure monitoring may be preferred). Central venous line and urinary catheter placement can be decided based on the patients' conditions, the selected anesthesia method, and surgical procedure.

When non-intubating techniques are employed, the lung exposed to atmospheric pressure is vulnerable to atelectasis due to the surgical opening of the parietal pleura during spontaneous breathing, and OLV begins. Hypoxia that may occur in this situation can usually be prevented by a face mask or nasally administered supplemental oxygen, unless the patient has an additional pulmonary comorbidity. Hypercapnia that may emerge during OLV should not be ignored.

Generally, this "persistent hypercapnia" is well tolerated by patients. However, end-tidal carbon dioxide ($EtCO_2$) assessment is vital for monitoring the patient's breathing pattern, rate, and hypercapnia that may occur during sedation and OLV. In the nonintubated patient, $EtCO_2$ can be monitored through specially designed nasal cannulas, an oxygen mask, or breathing circuit in patients via a subglottic device. Depth of anesthesia monitoring using the bispectral index (BIS) or patient state index (PSI) guides the appropriate depth of anesthesia to protect and maintain spontaneous breathing in the presence of sedation or subglottic device.

Anesthesia Method Selection

Nonintubating techniques render the surgical procedure possible in the absence of endotracheal intubation. Thereafter, various methods are then employed. The surgical procedure can be performed while the patient is fully awake, under mild sedation, under deep sedation, or under general anesthesia. Regional anesthesia or subglottic device use are also possible alternatives for these surgical procedures.

Regional anesthesia methods

Thoraic epidural anesthesia (TEA) is a well-known established technique among non-intubating techniques.[10] While reducing the myocardial oxygen demand, its advantages include blood flow improvement, left ventricular function enhancement, pulse rate and arrhythmia frequency reduction, ventilation and peak expiratory flow rate enhancement, pulmonary vascular resistance reduction, and diaphragmatic contractility improvement. However, disadvantages also exist, including hypotension, block failure, postdural headache, and, if opioids are used, respiratory depression and urinary retention.[11]

Placement of an epidural catheter between T1–T8 and preferably at T4–T5 level allows a T1–T8 block to provide an adequate anesthesia level while maintaining diaphragmatic respiration.[10] Short-acting or long-acting and low- or high-concentration local anesthetics may be preferred, considering the onset of the effect or surgery duration. However, since the patient may experience pain during intrathoracic manipulations, the use of low-concentration and very high-concentration local anesthetic solutions should be avoided, as this may cause a tidal volume decline due to motor block formation.[62] Maintenance can be provided as a bolus or continuous infusion. The use of infusion may be preferred as it can provide better hemodynamic stability and pain control compared to bolus administration.[59]

Paravertebral block

Paravertebral block (PVB), the regional anesthesia method frequently used as an alternative to TEA among nonintubated techniques, is associated with decreased hypotension and postoperative pulmonary complications and creates a unilateral block without bilateral sympathectomy. It may serve as an alternative to TEA in sepsis, coagulopathy, neurological disorders, and vertebral disorders where epidural catheter placement is difficult or contraindicated.

In the paravertebral space, fatty tissue, dorsal ramus, intercostal nerves, blood vessels, hemiazygos vein, and sympathetic nerve trunks are present. Since the intrathoracic fascia does not encompass this space, the nerves here are more sensitive to the effects of local anesthetics.[63] Although large-scale randomized studies evaluating PVB efficacy in nonintubated thoracic surgeries are warranted, a limited number of studies with small sample sizes report that PVBs added to nonintubated techniques using subglottic devices can provide effective and safe anesthesia.[64–67]

Intercostal nerve block

Intercostal nerve blocks (ICB) are a simple and safe method of anesthesia and can be employed intraoperatively under direct vision. ICB is reported to offer advantages in terms of pain control and analgesic consumption in nonintubated VATS and can be used in major surgeries, especially with developments in uni-portal VATS techniques.[52,68,69]

Serratus anterior plane block

In serratus anterior plane blocks (SAPB) a local anesthetic is injected in the plane between the serratus anterior and latissimus dorsi and between the chest wall and the serratus anterior muscles and are generally effective in T2–T9 dermatomes. Although a randomized controlled study is not available in the literature, a few case reports support the view that SAPB may be a suitable alternative in minor nonintubated VATS procedures.[70–73]

Erector spina plane block

While studies exist demonstrating the postoperative analgesic efficacy of erector spina plane block (ESPB) in thoracic surgeries,[74] few case reports exist mentioning ESPB efficacy in nonintubated VATS.[75,76]

Subglottic devices

Currently, anesthesia management, in which spontaneous breathing is preserved under the subglottic device such as laryngeal mask (LMA) and with the addition of regional anesthesia, is becoming very popular among non-intubating methods.[4] The requirement for sedation, especially due to anxiety, can sometimes suppress the awake patient's spontaneous breathing. Such cases benefit from deeper sedation that afford spontaneous breathing and the use of supraglottic airway devices for airway protection, particularly in combination with regional techniques.

In 2019, the consensus was reached in that the combination of intravenous anesthesia after LMA placement, ICB, superficial local anesthesia to the visceral pleura, and vagus nerve block was the optimal approach for nonintubated VATS.[54] The procedure is initiated with induction using propofol and fentanyl/remifentanil, followed by LMA placement once the BIS value is <60 or the PSI value is <50. To maintain anesthesia, propofol, remifentanil, and/or dexmedetomidine infusions are used. Dexmedetomidine infusion may be terminated during pleural cavity closure, and propofol and remifentanil infusions may be terminated during skin closure. With LMA, spontaneous breathing is allowed and oxygen is administered at 50% concentration with a flow rate of 2–3 L/min. The oxygen concentration should be titrated according to the patient's tolerance. If necessary, synchronized intermittent mechanical ventilation (SIMV) modes are preferred both for allowing spontaneous breathing and maintaining ventilation in the event of possible respiratory depression. Decreases in SpO_2 or increases in $EtCO_2$ can be solved through SIMV mode adjustments or via manual ventilation. Although it varies by patient, it is recommended that the SpO_2 value is >90 and the $PaCO_2$ value is <55–60 mmHg. This method also supplies a smoother intubation without the need for both preoxygenation and additional anesthetic agents except for a muscle relaxant during a possible need for intubation. Figure 1 demonstrate the standard anesthesia monitorization and adequacy of surgical view in a patient undergoing nonintubated VATS using LMA.

Complications

Hypoxia

In the event of surgeon-induced iatrogenic pneumothorax during non-intubating techniques, hypoxia may occur. However, this resulting hypoxia is minimal and a nasal cannula or mask with oxygen support can usually be employed to address this. If a subglottic device is used under general anesthesia that affords spontaneous breathing, manual ventilation in hypoxia situations or mechanical ventilation with low tidal volume in SIMV mode can be utilized. If the lung on the operated side has completely collapsed, airway resistance will be higher on the surgical side. During low tidal volume ventilation, most of the ventilated air will be diverted to the contralateral lung owing to this resistance. For this reason, the surgical side will swell only negligibly, and this will minimally affect the surgery.

Hypercarbia (hypercapnia)

Hypercapnia usually occurs due to hypoventilation and may be exacerbated by the effects of sedation or general anesthetic drugs. Generally, $EtCO_2$ values may be higher during nonintubation techniques compared to general anesthesia. Thus, caution should be exercised in patients with high pulmonary or intracranial pressure or arrhythmias. An accepted ventilation technique during thoracic surgery is permissive hypercapnia and is generally well tolerated and improves rapidly after the surgery.[77,78] In cases where $PaCO_2$ exceeds 60 mmHg, it can be intervened through manual ventilation or SIMV mode. Adjustment of the infusion speeds of the anesthetic agents is another option.

Cough

During non-intubating techniques, cough is the most common problem encountered. Sudden onset of cough will cause both the patient and the lungs to mobilize and render it difficult for the surgeon to complete the surgery. Insufficient blockade or sedation can cause hyperactivity and cough, and despite appropriate blockade and sedation, the cough reflex can be stimulated through manipulation of the bronchi. The cough reflex is primarily controlled by the vagus nerve. If awake thoracic surgery is conducted with epidural anesthesia, vagal tone predominance after sympathetic blockade following epidural anesthesia can theoretically increase bronchial tone and reactivity.

Different methods can induce cough reflex suppression; however, none are absolutely reliable.[79] Sedation with remifentanil may aid in suppressing the cough reflex but should be used with caution, as high doses can cause apnea and respiratory depression.[68] Intravenous lidocaine infusion may be an option, but toxicity is possible. Lidocaine nebulization of 2%–4% administered 30 min prior to surgery may be beneficial for intraoperative cough.[80] Nerve blockade may be introduced through the application of a local anesthetic in the Nervus vagus vicinity under direct thoracoscopic vision.[79,81] Despite all these possible applications, in some patients, the cough reflex may not be suppressed.

Intraoperative Intubation Requirement

In the literature, the rate of conversion from nonintubated technique to intubation varies between 2% and 11% for thoracic surgeries.[82] The most important factor for conversion to intubation is mediastinal mobility secondary to respiration, as it will lead to injuries that may result in surgical complications. Undesirable bleeding during non-intubating techniques is usually caused by an unexpected respiratory effort, cough reflex, or an insufficiently collapsed lung that obscures the surgeon's vision. Intubation reduces surgical stress by controlling breathing and protecting the contralateral lung.

Another important factor for intubation is the prolonged hypoxia or hypercapnia. Although there are no definitive criteria, intubation should be considered when oxygen saturation is 85% or less for more than 5 min or if PaO_2 is <60

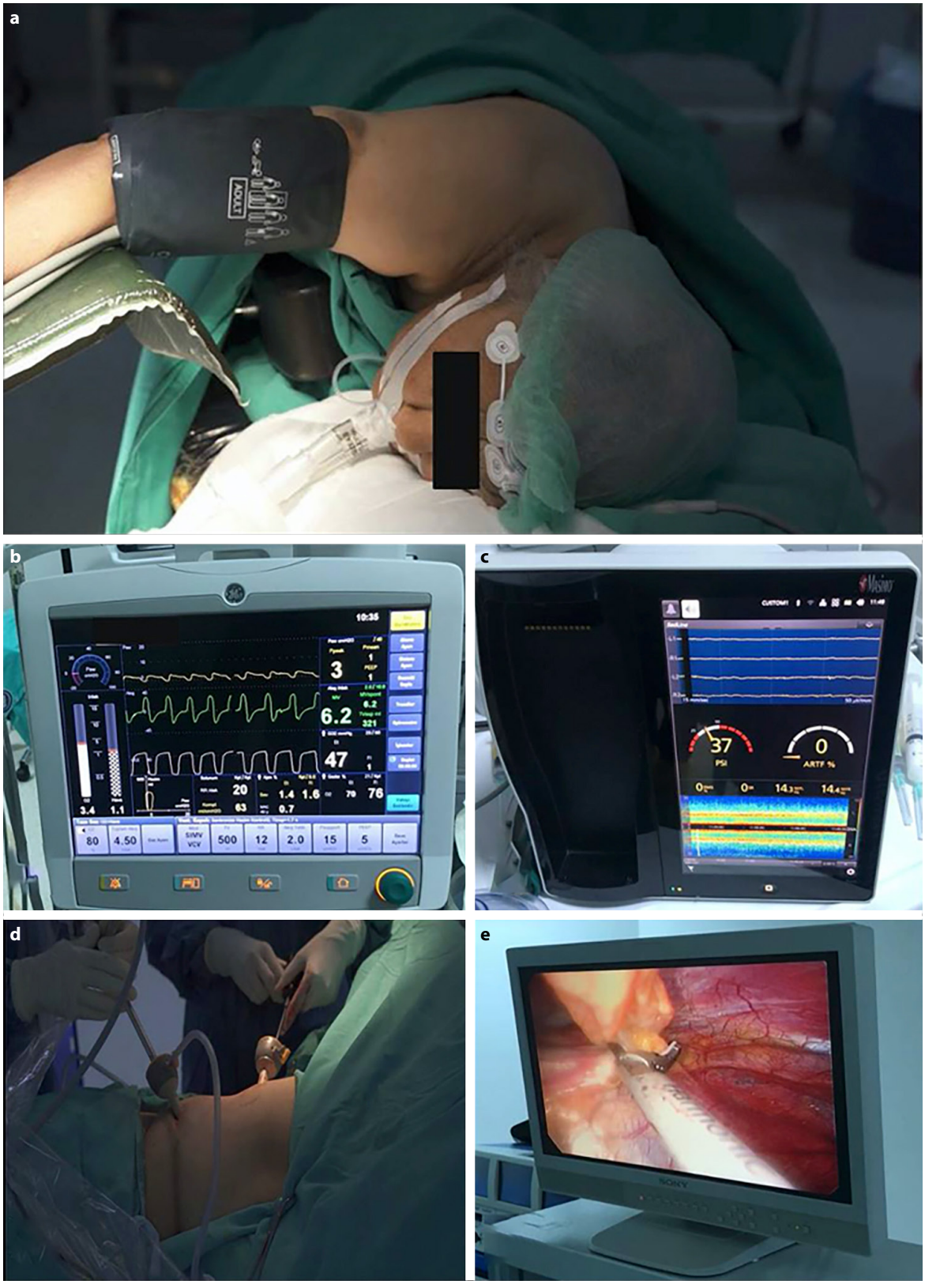

Figure 1. (a) Nonintubated video assisted thoracoscopic surgery under general anesthesia with laryngeal mask in a patient placed in the lateral decubitus position. **(b)** Spontaneous ventilation monitoring during one-lung ventilation. Patient is spontaneously breathing with tidal volumes of about 320 ml, a respiratory rate of 20 and minute ventilation of 6.2 L/min. **(c)** Patient state index (PSI) value is between 25 and 50. **(d)** The surgeon and the camera assistant are in the appropriate position for the surgery. **(e)** Sufficient surgical field of view is provided for the operation.

mmHg or $PaCO_2$ is >80 mmHg. Additionally, arrhythmias and hemodynamic changes accompanying these values may also affect the decision for intubation.[54]

For the conversion to intubation, it is essential that the surgeon and anesthesiologist evaluate the patient together to arrive at a decision. Patients may be in the lateral decubitus position during surgery and emergent intubation may need to be performed in this position. Some authors suggest that intubation can be performed in the lateral decubitus position, while others suggest that the patient be immediately covered with sterile drapes and intubated while in the supine position.[58] Here, the joint decision and the anesthesia and surgical team experience should direct the course of action. The combination of single-lumen endotracheal tube and bronchial blocker for intubation in the lateral decubitus position may be a more feasible option than DLTs.[68,77]

Conclusion

In thoracic surgery, nonintubating techniques are innovative procedures that can be conducted and managed safely and successfully by experienced anesthesia teams. Although their long-term results have not been clearly elucidated yet, these techniques should be considered as an alternative to thoracoscopic surgery under OLV, especially in patients with a high intubation risk. The challenges encountered in the initial application of this technique can be overcome through sufficient training and experience. Video-assisted thoracic surgeries in nonintubated patients are increasingly popular. Nevertheless, more studies are warranted to determine which patient groups will benefit these techniques and to investigate their effects on morbidity and mortality.

Disclosures

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RESEARCH ARTICLE

Comparison of Bretschneider's Histidine–tryptophan–ketoglutarate Cardioplegia Solution and Conventional Blood Cardioplegia Solution in Terms of Postoperative Acute Kidney Injury and Outcome Parameters

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ABSTRACT

Objectives: This study aimed to compare Bretschneider's histidine–tryptophan–ketoglutarate (BHTK) and blood cardioplegia in terms of postoperative acute kidney injury (AKI) and outcome parameters in patients who underwent open-heart valve surgery.

Methods: A total of 94 patients who underwent open-heart valve surgery between January 2016 and November 2021 were retrospectively evaluated. According to the administration of BHTK and blood cardioplegia, patients were stratified into two groups. Postoperative Kidney Disease Improving Global Outcomes was compared in terms of development of AKI and outcomes according to staging.

Results: A total of 31 patients in the BHTK group and 63 patients in the blood cardioplegia group were evaluated. No statistical difference was found between the groups in terms of postoperative AKI ($p>0.05$). Postoperative 24 and 48 h blood urea nitrogen (BUN) was higher in the BHTK group ($p=0.007$ and $p=0.023$). This difference equalized on the 7th day. No statistical difference was found in the mechanical ventilation time, intensive care unit and hospital stay, and 30-day mortality.

Conclusion: Literature evaluating the systemic effects of BHTK solution is limited. In our study, although no difference was found between BHTK and blood cardioplegia in terms of AKI development, the increase in BUN in the BHTK group was remarkable. Further studies exploring the clinical impact of this finding are warranted.

Keywords: Acute kidney injury, blood cardioplegia, blood urea nitrogen, bretschneider's histidine-tryptophan-ketoglutarate, myocardial protection

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Introduction

Cardioplegia solutions are formulations that induce diastolic arrest in the heart to maintain cardiac immobility and a blood-free surgical field during open-heart surgery. Through preserving myocardial energy reserves, preventing osmotic and electrolyte imbalances, and buffering acidosis, these solutions basically increase tolerance to ischemia and reperfusion injury.[1] Bretschneider's histidine–tryptophan–ketoglutarate (BHTK or Custodiol) solution is an intracellular crystalloid cardioplegia solution that also contains histidine–tryptophan–ketoglutarate with trace amounts of calcium (Ca) to hamper low sodium (Na) and calcium paradox.[2]

Blood cardioplegia content can vary. It is usually acquired by mixing the autologous blood extracted from the extracorporeal circulation with the crystalloid solution (contain-

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ing sodium bicarbonate [NaHCO3], magnesium [Mg], and potassium chloride [KCl], among others) in different proportions when the patient is in cardiopulmonary bypass (CPB) and is used in repeated doses.[1]

The development and use of a BHTK cardioplegia solution remarkably improves myocardial protection during open-heart surgery. However, a few clinical studies[3] have reported on the metabolic changes caused by this crystalloid cardioplegia solution, which enters the systemic circulation in large volumes, and its influence on end organs such as the kidney.

The most prevalent complication following cardiac surgery is acute kidney injury (AKI), with reported incidence rates ranging from 5%–43%.[4] AKI is a clinical condition associated with substantial mortality and morbidity, independent of other variables.[5] A mortality rate of 60% was observed in patients who develop postoperative AKI. The mortality rate following open-heart surgery ranges from 2%–8% and reaches 60% in patients who develop postoperative AKI.[6,7]

This study aimed to compare BHTK cardioplegia solution and conventional blood cardioplegia solution in terms of development of postoperative AKI and outcomes in patients who underwent open-heart valve surgery.

Methods

After the ethics committee approval was obtained with the decision number 586 dated 12.23.2021, 94 patients who underwent open-heart surgery for aortic valve replacement (AVR), mitral valve replacement (MVR), and AVR + MVR between January 2016 and November 2021 in Izmir Katip Çelebi University Atatürk Training and Research Hospital Cardiovascular Surgery clinic were retrospectively reviewed. From the archives, the hospital information operating system and file records were used. Patients with a known acute renal failure, chronic renal failure, total circulatory arrest, and cerebral perfusion during CPB were excluded from the study. Patients were stratified into two groups based on the administration of BHTK and blood cardioplegia. Demographic data such as comorbidities, history of contrast agent use within the last week, history of cardiac surgery, revision surgery, preoperative ECG rhythm, and nephrotoxic agent use were extracted.

Creatinine clearance (CC) was determined using the Cockcroft–Gault formula (CC [mL/min]=(140-age [years]×weight [kg]×[0.85 if female]/[72×serum creatinine [mg/dL]). The inotrope score (IS) was determined using the formula IS=dopamine dose (mcg/kg/min) + dobutamine dose (mcg/kg/min)+100×epinephrine dose (mcg/kg/min).

Moreover, the preoperative results of the complete blood count, biochemistry, coagulation parameters, and transthoracic echocardiography were recorded. Also, whether the case was an emergency or elective surgery, surgery type, cross-clamp duration, CPB duration, surgery duration, intraoperative IS, amount of ultrafiltration during CPB, amount of intraoperative fluid administered, amount of intraoperative diuresis and diuretic use, intraoperative defibrillation requirement, and intra-aortic balloon pump (IABP) use were recorded. In addition to these, such data as postoperative IS, amount of drainage in the first 24 h, extubation time, length of intensive care unit stay, length of hospital stay, arrhythmia, new-onset atrial fibrillation (AF), IABP administration, need for renal replacement therapy, 30-day mortality, AKI (according to Kidney Disease Improving Global Outcomes [KDIGO] grading scale), and postoperative complications (respiratory, neurological, gastrointestinal, bleeding, and infection complications) were also recorded. This study was conducted in accordance with the 1964 Declaration of Helsinki and its subsequent amendments.

Cardioplegia Administration

A blood cardioplegia solution was prepared using 3 mmol Mg, 30 mmol potassium (K), and 10 mmol NaHCO3 into 1 L of isothermic blood content to achieve cardiac arrest in patients receiving blood cardioplegia as a standard. The BHTK solution composition is shown in Table 1.

To maintain cardiac arrest, cardioplegia was repeated every 20 min in patients receiving antegrade blood cardioplegia. In cases where both antegrade and retrograde cardioplegia were used, retrograde cardioplegic solution was continuously administered 20 min after antegrade cardioplegia. Conversely, in cases where the BHTK solution was administered, it was repeated 90 min later if warranted.

Statistical Methods

All statistical analyses were conducted using SPSS 22 program. Descriptive statistics was expressed using mean and standard deviation for continuous variables and numbers

Table 1. BHTK (custodiol) solution components

Components	Concentration (mmol/L)
Na	15
K	9
Mg	4
Ca	0.02
Histidin	198
Triptofan	2
α-ketoglutarat	1
Mannitol	30
pH	7.02–7.20
Osmolarite	290 mosmol/kg

BHTK: Bretschneider histidine tryptophan ketoglutarate.

Table 2. Sociodemographic characteristics and preoperative clinical findings of the patients

Variables	Blood cardioplegia (n=63)		BHTK cardioplegia (n=31)		p
	n	%	n	%	
Age	56.22±13.07		50.03±14.74		0.041*
EuroSCORE II	1.48±1.03		2.23±1.34		0.001*
STS risk of death	1.23±0.86		1.65±1.12		0.043*
STS kidney damage	1.13±0.90		1.47±1.09		0.122
STS mortality/morbidity	8.60±4.02		10.79±4.64		0.045
Sex (male)	33	52.4	15	48.4	0.716
Smoking	24	38.1	14	45.2	0.512
Hypertension	28	44.4	13	41.9	0.818
Diabetes	6	9.5	7	22.6	0.085
Coronary artery disease	20	31.7	10	32.3	0.960
Myocardial infarction	0	0	1	3.2	0.330
Heart failure	4	6.3	5	16.1	0.128
Decreased LVEF (<35%)	1	1.6	4	12.9	0.039*
Dyslipidemia	9	14.3	4	12.9	0.855
Carotid artery stenosis	2	3.2	0	0	0.447
Peripheral artery disease	0	0	1	3.2	0.330
COPD	10	15.9	2	6.5	0.198
Asthma	3	4.8	2	6.5	0.536
Stroke	9	14.3	4	12.9	0.855
Contrast history within 1 week	23	36.5	7	22.6	0.173
Cardiac surgery history	9	14.3	12	38.7	0.008*
Redo case	9	14.3	10	32.3	0.041*
Pre-op atrial fibrillation	24	38.1	15	48.4	0.341
Pre-op atrial flutter	1	1.6	0	0	0.670
Drug use	63	100	31	100	–
Insülin	2	3.2	3	9.7	0.199
Beta blocker	43	68.3	26	83.9	0.107
Statin	6	9.5	3	9.7	0.623
Aspirin	51	81	23	74.2	0.452
Diuretic	39	61.9	24	77.4	0.133
Steroid	1	1.6	1	3.2	0.553
Nephrotoxic drug use	10	15.9	9	29	0.135
ACEI/ARB	10	15.9	6	19.4	0.673
Aminoglycoside	0	0	1	3.2	0.330
Amphotericin B	0	0	0	0	–
Cyclosporine/tacrolimus	0	0	0	0	–
NSAID	0	0	3	9.7	0.034*
Vancomycin	0	0	1	3.2	0.330

*: p<0.05 was considered statistically significant. Values are expressed as frequency (%), mean±SD and n. BHTK: Bretschneider histidine tryptophan ketoglutarate; EuroSCORE: European System for Cardiac Operative Risk Evaluation; STS: Society of thoracic surgeons; LVEF: Left ventricular ejection fraction; COPD: Chronic obstructive pulmonary disease; ACEI: angiotensin converting enzyme inhibitor; ARB: Angiotensin-2 rejeptor blocker; NSAID: non-steroidal anti-inflammatory drug.

and percentages for categorical variables. Prior to analysis, conformation of data to the normal distribution was evaluated using skewness and kurtosis values, normality tests, and histogram graphics. To determine the differences in the mean values between the groups, the independent variables T test or dependent variables T test was used for the variables that conformed to the normal distribution. The Mann–Whitney U test or Wilcoxon test was used for the variables

Table 3. Comparison of the surgery types and intraoperative data of the patients

Variables	Blood cardioplegia (n=63)		BHTK cardioplegia (n=31)		p
	n	%	n	%	
Total amount of antegrade cardioplegia (mL)	1128.57±457.61		1277.41±431.82		0.064
Total amount of retrograde cardioplegia (mL)	1941.26±1478.84		0±0		–
Cross clamp time (min)	68.88±24.15		85.09±28.66		0.009*
CPB duration (min)	101.44±31.46		120.09±28.72		0.007*
Operation time (min)	211.26±48.04		250.41±53.88		0.001*
Intraoperative inotrope score	24.52±36.44		33.23±35.76		0.049*
Ultrafiltration amount (mL)	122.22±318.99		567.74±672.12		0.0001*
Preoperative CVP	10.77±4.08		11.87±4.25		0.232
Total amount of fluid given (mL)	4099.84±953.29		3887.09±1199.02		0.353
Total amount of diuresis (mL)	1861.58±867.36		2170.96±855.15		0.106
Type of surgery					
AVR	25	39.7	9	29	0.512
MVR	30	47.6	16	51.6	
AVR+MVR	8	12.7	6	19.4	
Urgency of surgery	1	1.6	0	0	0.670
Defibrillation need	19	30.2	9	29	0.911
IABP use	0	0	2	6.5	0.106
Intra operative diuretic use	28	44.4	18	58.1	0.214
Intra op ERT (unit)					
0	37	58.7	15	48.4	0.514
1	12	19	9	29	
≥2	14	22.2	7	22.6	
Intra op FFP (unit)					
0	42	66.7	18	58.1	0.318
1	11	17.5	4	12.9	
≥2	10	15.9	9	29	

*: p<0.05 was considered statistically significant. Values are expressed as frequency (%), mean±SD and n. BHTK: Bretschneider histidine tryptophan ketoglutarate; CPB: Cardiopulmonary bypass; CVP: Central venous pressure; AVR: Aortic valve replacement; MVR: Mitral valve replacement; IABP: Intra-aortic balloon pump; ERT: Erythrocyte suspension; FFP: Fresh frozen plasma.

that did not fit the normal distribution. To determine the differences in the categorical variables between groups, a Ki-square test or Fischer's exact test was used. The difference in the values between the means of repeated measurements in the groups were evaluated using the Mann–Whitney U test. Furthermore, in cases of more than two time zones, the evaluation of time, groups, and joint effect was conducted using the two-way analysis of variance test on repeated measures. Post hoc analyses were performed using the Bonferroni test. In all analyses, statistical significance was set at p<0.05.

Results

Of the 94 patients (mean age 54.18±13.88 years, 48 males and 46 females), 31 were in the BHTK group and 63 in the blood cardioplegia group. The demographic characteristics and preoperative findings of the patients are shown in Table 2. In the BHTK group, the left ventricular ejection fraction was lower, while the number of patients with a history of repeated surgery and cardiac surgery was greater, including the cross-clamp time, CPB time, operation time, and intraoperative IS, each being greater. No significant difference was found between the two groups regarding IABP use, the need for intraoperative defibrillation, postoperative arrhythmia, new-onset AF, or the need for a pacemaker. Table 3 presents the surgical procedures, intraoperative data, and a comparison of cardioplegia varieties and number of patients.

No difference was found between the two groups in terms of postoperative AKI development, 30-day mortality, new-onset AF, and other complications (Table 4).

Comparing the blood urea nitrogen (BUN) value according to time and cardioplegia type and determining the common effect, a significant difference was found in both cardioplegia groups according to time (p<0.05). Postoperative

Table 4. Comparison of patients in terms of postoperative complications, AKI, and mortality

Variables	Blood cardioplegia (n=63)		BHTK cardioplegia (n=31)		p
	n	%	n	%	
30 day mortality	2	3.2	2	6.5	0.401
AKI	21	33.3	12	38.7	0.650
KDIGO (if AKI+; n=33)					
1	18	85	9	75	0.830
2 or 3	3	15	3	25	
Postoperative RRT	1	1.6	2	6.5	0.252
Highest creatinine day					
1–2	50	79.4	27	87.1	0.522
3–4	7	11.1	3	9.7	
5–7	6	9.5	1	3.2	
Arrhythmia	1	1.6	1	3.2	0.553
AF	13	20.6	9	29	0.366
Newly onset AF	4	6.3	3	9.7	0.421
Reoperation	7	11.1	3	9.7	0.832
Infection	12	19	3	9.7	0.243
Respiratory dysfunction	6	9.5	2	6.5	0.616
Neurological complication	0	0	1	3.2	0.330
Temporary pacemaker	28	44.4	20	64.5	0.067
Bleeding	46	73	20	64.5	0.397
Gastrointestinal complication	2	3.2	0	0	0.447

Values are expressed as frequency (%), mean±SD and n. AKI: Acute kidney injury; BHTK: Bretschneider histidine tryptophan ketoglutarate; KDIGO: Kidney disease improving global organization; RRT: renal replacement therapy; AF: Atrial fibrillation.

24 and 48 h BUN values were found to be significantly higher in the BHTK cardioplegia group than the blood cardioplegia group (p=0.007 and p=0.023). This difference was equalized on the 7th day. It was determined that the time and cardioplegia type showed a remarkable joint effect on the BUN value (p<0.05) (Table 5). The blood BUN value changes according to time in groups are shown in Figure 1.

In terms of postoperative mechanical ventilation time, length of intensive care unit and hospitalization stay, and extubation time, no significant difference was found (Table 6).

Discussion

In this study, we compared BHTK and blood cardioplegia in terms of postoperative AKI and outcome parameters in patients who underwent open-heart valve surgery. In terms of postoperative AKI development in the study, no statistically significant difference was observed between the two cardioplegia methods.

One of the most common and serious complications in the postoperative period following open-heart surgery is AKI, which has been associated with a prolonged intensive care and hospital stay and increased mortality.[8]

In a study involving 1900 patients, Viana et al.[1] compared blood cardioplegia with BHTK cardioplegia. Although severe left ventricular dysfunction, EuroSCORE 2, cross-clamp, and CPB duration parameters were higher in the BHTK group, no difference was found in the study in terms of postoperative kidney damage,[1] which corroborates with our results.

In another study, BHTK and blood cardioplegia were compared for AVR surgery in 1650 patients with propensity score matching, and no difference was found between the two groups in terms of kidney damage requiring dialysis.[9]

BHTK is an intracellular solution that was used in the 1970s for cardioplegic arrest. Its effects are demonstrated through the induction of hyperpolarization. Histidine buffers ischemia-induced acidosis, while tryptophan stabilizes the cell membrane. Alpha ketoglutarate is the main component of the Krebs cycle in the cell. The mannitol in the solution contributes to the maintenance of cellular osmolarity.[10]

The cardiac effects of the BHTK solution have been extensively studied in the literature; however, the number of studies systematically investigating the metabolic changes induced by these solutions in other vital organs remains limited.

Table 5. Comparison of blood urea nitrogen (BUN) by time and cardioplegia type and determining the common effect

Variables	1. BUN value before the operation	2. BUN value 24 hours after the operation	3. BUN value 48th hour after the operation	4. BUN value 7th day after the operation
Blood cardioplegia	18.67±5.68	20.51±6.96	24.24±9.33	17.45±9.69
BHTK cardioplegia	20.80±8.70	25.43±8.81	28.53±12.59	17.83±9.82
		Wilks' Lambda	**F**	**p**
Time		0.489	30.671	0.0001**
Time*group		0.907	3.024	0.034**
Group		–	3.590	0.061
		***Post-hoc* bonferonni**		
Time (Blood cardioplegia)		1<2; 1<3; 1=4; 2<3; 2>4; 3>4		
Time (BHTK cardioplegia)		1<2; 1<3; 1=4; 2=3; 2>4; 3>4		

*: Two-way repeated measures Analysis of Variace (ANOVA); **: Data expressed as Mean±SD and n, %. BHTK: Bretschneider histidine tryptophan ketoglutarate.

A study evaluating amino acid and nitrogen metabolism changes caused by histidine degradation contained in BHTK has exhibited that large amounts of histidine pass into the systemic circulation due to the application of BHTK in higher volumes compared to blood cardioplegia. Furthermore, it has been demonstrated that nitrogen atom metabolites in the imidazole ring structure are converted to either ammonium ions or urea.[11] In a study using urine samples from 100 patients undergoing open-heart surgery, to investigate the metabolic changes caused by the BHTK solution, dysregulation of glutamine/glutamate, purine/pyrimidine, vitamin B6, and histidine metabolism was explored. The researchers of this study highlighted the need for further study into the fundamental processes underlying both its possible detrimental effects and its organ-protecting properties.[3]

In a trial comparing BKTK solution and BKTK-N solution employed during CPB, it was revealed that BHTK causes proximal tubule swelling and cytochrome-C release in porcine kidney, which may be associated with AKI.[12]

Our study revealed that the BHTK group showed significantly higher BUN values during the 24 and 48 h postoperatively. On day 7, it was also observed that the elevation spontaneously resolved. In the statistical analysis of BUN, creatinine, glomerular filtration rate, and CC, only the BUN value was found to be affected by time and cardioplegia type, which can be explained by the fact that BHTK produces a large quantity of urea and ammonium, which are histidine metabolites. However, we failed to find any clinical studies in parallel with that conclusion. To better understand the practical implications of this finding, we recommend conducting a larger randomized controlled trial, emphasizing the need to explore regarding the impact of this finding on renal effects in tissue culture.

One of the major concerns accompanying cardiac surgery is myocardial injury, which is associated with the development of arrhythmia, major cardiac and renal morbidities, prolonged intensive care unit and hospital stay, and high mortality risk.[13]

In our clinic, selecting the cardioplegia solution is a joint decision of the cardiac surgeon, anesthesiologist, and

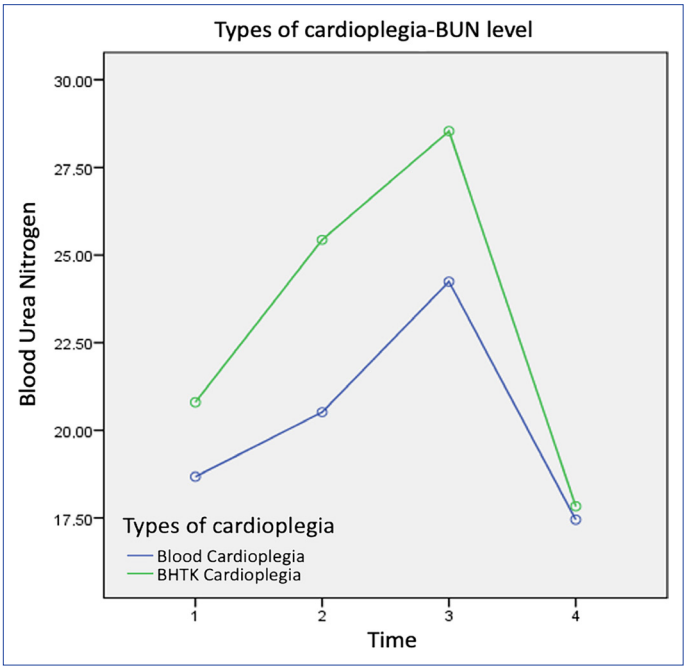

Figure 1. Change of blood urea nitrogen value according to time and groups.
BHTK: Bretschneider histidine tryptophan ketoglutarate.

Table 6. Comparison of the postoperative data of the patients

Variables	Blood cardioplegia (n=63)		BHTK cardioplegia (n=31)		p
	n	%	n	%	
Postoperative CVP	9.84±3.28		11.06±3.47		0.099
Postoperative inotrope score	23.26±39.76		36.53±38.10		0.010*
Drainage amount (mL) in the first 24 hours	461.11±236.48		546.12±516.00		0.505
Extubation time (hour)	14.97±13.81		16.51±19.96		0.456
Length of stay in intensive care (day)	3.85±4.15		4.03±2.19		0.109
Length of stay in hospital (day)	10.36±9.53		11.61±8.28		0.151
Post operative atrial fibrillation	10	15.9	9	29	0.135
Post operative IABP	0	0	1	3.2	0.330
Postoperative ERT (unit)					
0	42	66.7	16	51.6	0.359
1	12	19	8	25.8	
≥2	9	14.3	7	22.6	
Postoperative FFP (unit)					
0	36	57.1	13	41.9	0.305
1	10	15.9	5	16.1	
≥2	17	27	13	41.9	

*: p<0.05 was considered statistically significant. Values are expressed as frequency (%), mean±SD and n. BHTK: Bretschneider histidine tryptophan ketoglutarate; CVP: Central venous pressure; IABP: Intraaortic balloon pump; ERT: Erythrocyte suspension; FDP: Fresh frozen plasma.

perfusionist. We prefer the BHTK solution for valve operations with worse cardiac performance in cases where we foresee a prolonged operation time and where an uninterrupted view of the field could be required in terms of surgical technique. Obviously, this is the rationale for the difference in cross-clamp, CPB, and operation times between the two groups in our study.

Based on the results of a recent large meta-analysis comparing BHTK and blood cardioplegia for myocardial protection, BHTK solution was found to have the same efficacy and safety as other cardioplegic solutions in most clinical parameters.[10]

IS or the need for inotropes, IABP use, arrhythmia incidence, and cardiac biomarkers are the parameters evaluated while detecting myocardial damage in an open-heart surgery.[9,14–16]

In a prospective randomized study comparing blood and BHTK cardioplegia with a total of 345 patients undergoing AVR, no significant difference was found between the two groups in terms of spontaneous sinus rhythm, inotropic agent use, AF development, mechanical ventilation duration, perioperative myocardial ischemia, and mortality after opening the aortic cross-clamp.[17] Except for the use of inotropes, these findings are also consistent with our study. We also found that IS during and after surgery was higher in the BHTK cardioplegia group. However, any difference was not observed between both groups in terms of ejection fraction (EF) values in the preoperative and postoperative repeated measurements.

In our study, no difference was found between the groups in terms of preoperative and postoperative AF incidence, the need for defibrillation during surgery, new-onset AF, the need for temporary/permanent pacemaker, and IABP. Our study findings corroborate with the literature.[18,19]

Edelman et al.[20] reported that no difference was found for mortality similar to our results in their systematic review comparing BHTK and conventional cardioplegia, based on the meta-analysis results including 14 studies. Additionally, in terms of postoperative complications, bleeding, reoperation, mechanical ventilation time, and intensive care unit stay and hospital stay, no difference was found between the two groups.

Limitations

One of the study limitations was the single-center and retrospective nature of the study. Thus, the findings should be confirmed through multicenter and prospective studies. Moreover, the patient sample was small, and plasma and urine biomarkers neutrophil gelatinase-associated lipocalin, interleukin-18 (NGAL, IL-18, cystatin C, kidney injury molecule-1) were not investigated to identify cardiac biomarkers and AKI earlier.

Conclusion

Based on our data, we can conclude that BHTK solution provides effective myocardial protection and improves clinical outcomes during open-heart valve surgery. Additionally, we would like to highlight that this result should be supported by cardiac biomarkers. No difference was found between the two groups in terms of AKI development according to the KDIGO grading scale. However, BUN elevation, which is the histidine metabolite, is remarkable in the BHTK group.

Disclosures

Ethics Committee Approval: The study was approved by The İzmir Katip Çelebi University Non-interventional Clinical Research Ethics Committee (Date: 23/12/2021, No: 586).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

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Authorship Contributions: Concept – E.G.D., S.G.; Design – A.S.T., B.E.G.; Supervision – M.A., A.G.; Materials – A.S.T.; Data collection &/or processing – E.G.D., A.S.T.; Analysis and/or interpretation – S.G., B.E.G.; Literature search – M.A., A.S.T.; Writing – S.G., E.G.D.; Critical review – N.K., A.G.

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RESEARCH ARTICLE

Potential Role of Erector Spinae Plane Block on Neutrophil-Lymphocyte Ratio in Cardiac Surgery Patients

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ABSTRACT

Objectives: In cardiac surgery, a successful erector spinae plane (ESP) block has been demonstrated within the scope of multimodal analgesic approach. This study aimed to comparatively evaluate the effect of ESP block used in cardiac surgery on neutrophil-lymphocyte ratio (NLR).

Methods: Patients who underwent an ESP block and conventional analgesia technique for coronary artery bypass grafting surgery were retrospectively compared. Postoperative pain scores, analgesic consumption, extubation times, and intensive care unit (ICU) and hospital stays were recorded with patient and operative data. As the study's primary outcome, NLR values were calculated from the hemogram as an indicator of inflammation during the preoperative period and 3 days postoperatively.

Results: A total of 97 patients who underwent coronary artery bypass graft surgery with cardiopulmonary bypass were investigated. The highest pain score (p=0.016), total opioid (p=0.008) and acetaminophen (p=0.009) consumption, extubation (p=0.024), and ICU stay (p=0.045) in the first 24 h after extubation were significantly lower in the ESP group. NLR (p=0.019, p=0.046, and p=0.038, respectively) was significantly lower in the ESP group in the first 3 days.

Conclusion: In addition to being associated with less opioid use in the first 24 h in the postoperative pain management of cardiac surgery, ESP block reduces NLR 3 days postoperatively.

Keywords: Cardiac surgery, erector spinae plane block, neutrophil lymphocyte ratio

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Introduction

Perioperative pain management plays a crucial role in the management of patients undergoing cardiac surgery. In cardiac surgery, owing to surgical manipulation such as sternotomy, sternal retraction, internal mammary artery removal, and chest tube placement, pain is described as moderate to severe. Inadequate pain management results in hemodynamic deterioration associated with systemic complications such as atelectasis, pneumonia, and stasis of bronchial secretions (pulmonary); increased oxygen consumption and tachycardia (cardiovascular); muscle weakness (musculoskeletal system); and increased neurohormonal response.[1] Multimodal opioid-sparing pain management plans are strongly recommended by the Society for Advanced Post-Surgical recovery guidelines for perioperative cardiac surgical care (class I recommendation).[2] These include regional analgesia and intravenous (IV) and oral analgesics. Opioids can induce nausea, vomiting, pruritus, and respiratory depression when used only for analgesia.

An acute inflammatory response is also triggered by factors that cause postoperative pain (repeated surgical tissue trauma, bone fracture and dislocation, arterial dissection, tissue retraction, and vein removal). Inflammation and pain are interrelated, as the local release of proinflammatory mediators leads to peripheral sensitization, leading to increased pain. Host immunity and inflammatory states can be evaluated using serum markers such as neutrophils, lymphocytes, and platelets. Serum markers

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such as the neutrophil/lymphocyte ratio (NLR) have become invaluable owing to their noninvasive nature, simplicity, and predictability.[3]

Regional anesthesia techniques not only facilitate patient rehabilitation due to pain palliation but also modulate the inflammatory response as a result of surgical injury with various mechanisms at different levels.[4,5] Erector spinae plane (ESP) block is a myofascial plane block in which a local anesthetic is injected in the plane between the spina muscle or the transverse process.[6] Based on available evidence, in postoperative pain management in cardiac surgery, many studies elucidate that ESP block is associated with improved postoperative analgesia, has less opioid requirement, and affords faster recovery.[7–11] However, no literature exists exploring the effects of ESP block on surgery-induced inflammation. This study aimed to investigate the effects of ESP block employed for postoperative analgesia in cardiac surgery on surgery-induced inflammation using NLR.

Methods

After ethics committee approval (ethical no: E1-22-2982, 19.10.2022), patients who underwent on-pump coronary artery bypass graft (CABG) performed in the cardiovascular operating room between 01.01.2022 and 30.03.2022 were included in the study. Patient records from the hospital archive and hospital information systems were retrospectively searched. Emergency operations; recurrent cardiac surgery; combined cardiac surgery procedures; patients with preoperative requirement for intraaortic balloon pump or high inotropic support, with primary pulmonary hypertension, and with ejection fraction <40%; patients with systemic inflammatory or autoimmune disease, liver disease, malignancy, and chronic kidney disease were excluded from study. All procedures were performed in accordance with the Declaration of Helsinki guidelines.

Retrospectively, intervention and control groups were created based on patients who underwent CABG between the specified dates by the same anesthesia and surgical team. An ultrasound-guided (PHILIPS Affiniti 50 color Doppler ultrasound device, Philips L12-5 50-mm linear array transducer) ESP block (bilateral, 20 mL 0.25% bupivacaine per side) was performed for the intervention group in the prone position prior to anesthesia induction by an experienced anesthesiologist. It was observed that a standard anesthesia technique and postoperative care protocol were applied to both groups, except for the ESP block, and analgesics were administered according to the reported pain score. Pain assessment was conducted using the visual analog scale (VAS, 10 as maximum pain and 0 as no pain) records available on the intensive care unit (ICU) observation sheet.

Demographic data (age, sex, height, and body weight), previous comorbidities, smoking status, and laboratory data including serum creatinine, albumin, estimated glomerular filtration rate, hemoglobin, neutrophil, lymphocyte, platelet, and C-reactive protein (CRP) parameters were recorded. Additionally, cardiopulmonary bypass (CPB), cross-clamp, and total procedure durations were recorded. Postoperative blood counts (hemoglobin, hematocrit, neutrophil, and lymphocyte value), amount of opioid and nonopioid analgesics, extubation time, length of hospital and ICU stay, and the patient's highest pain score reported daily were recorded. Required opioids were converted to oral morphine equivalents (OME) using the National Centers for Drug and Alcohol Research and Centers for Disease Control guidelines.[12,13]

Statistical Analysis

Descriptive statistics were presented as absolute numbers (n) and percentages (%) for categorical variables. Moreover, the median-interquartile range (25^{th}–75^{th} percentiles) was used for non-normally distributed data and the mean standard deviation for normally distributed data. Using the χ 2 test, categorical variables were compared. Continuous variables between with and without ESP block using the Mann–Whitney U test or independent samples t-test were compared, based on the Kolmogorov–Smirnov test for normality. For all analyses, statistical significance was set at $p<0.05$. Literature on the effect of ESP on the inflammatory response was limited. Hence, in this study, power analysis was conducted on 97 patients using the data obtained. NLR (1^{st} measurement with a difference between groups) values were used for power analysis after completion of the study. According to this, power analysis was performed using G* Power 3.1.9.7 statistical package program: n=97 (n1=55, n2=42), $\alpha=0.05$, and effect size (d)=0.76; power=93% was found.

Results

Within the specified 3-month period, it was determined that 118 patients underwent CABG operation. Among them, it was observed that 12 patients underwent off-pump CABG, and nine patients underwent reoperation secondary to postoperative bleeding. Preinduction ESP block (ESP group) was performed in 42 of the remaining 97 patients. The conventional group consisted of 55 patients (group C). Baseline demographic data, American Society of Anesthesiologists score, smoking status, comorbidities, number of bypassed grafts, procedure times, and preoperative laboratory data were similar between groups (Table 1).

The amount of opioids expressed in OME and total acetaminophen within the first 24 h after extubation was

Table 1. Basic demographic data, procedure times, and preoperative laboratory data

	Group C (n=55)		Group ESP (n=42)		p*
	n	%	n	%	
Gender (male)	44	80.0	34	81.0	0.907
Age (years), mean±SD	60.90±7.9		62.35±9.8		0.427
BMI (kg/m^2), mean±SD	28.76±4.2		28.08±4.1		0.432
ASA					
II	17	30.9	20	47.6	0.093
III	38	69.1	22	52.4	
Smoking status					
Never smoker	28	50.9	14	33.3	0.159
Former smoker	2	3.6	4	9.5	
Current smoker	25	45.5	24	57.1	
HT	35	63.6	26	61.9	0.861
DM	27	49.1	15	35.7	0.188
COPD	4	7.3	8	19.0	0.081
Stroke/TIA	3	5.5	3	7.1	0.732
LVEF (%), mean±SD	52.60±8.3		53.07±7.4		0.774
Number of grafts					
CABG×2	10	18.2	11	26.2	0.661
CABG×3	17	30.9	14	33.3	
CABG×4	23	41.8	15	35.7	
CABG×5	5	9.1	2	4.8	
CC time (min), mean±SD	74.65±26.6		69.15±19.9		0.266
CPB time (min), mean±SD	112.66±32.5		101.11±28.9		0.073
Procedure time (min), mean±SD	309.10±60.0		313.37±53.4		0.717
Preoperative laboratory data					
Hemoglobin (g/L), mean±SD	13.78±1.7		13.47±1.2		0.336
Serum creatinine (mg/dL), mean±SD	0.96±0.2		0.90±0.2		0.192
eGFR (ml/ min /1.73m^2), mean±SD	80.83±16.1		83.95±13.9		0.321
HbA1c (%), median (IQR)	6.70 (5.8–7.1)		5.90 (5.6–6.9)		0.052
CRP (mg/L), median (IQR)	2.0 (1.02–4.7)		2.19 (1.0–5.05)		0.686
Serum albumin (g/ dL), median (IQR)	42 (40–45)		42 (42–44)		0.176

*: The independent samples t-test and Mann–Whitney U test were used for continuous variables; the χ^2 was performed for categorical variables (n, %). ESP: Erector spinae plane; SD: Standard deviation; BMI: Body mass index; ASA: American Society of Anesthesiologists; HT: Hypertension; DM: Diabetes mellitus; COPD: Chronic pulmonary disease; TIA: Transient ischemic attack; LVEF: Left ventricular ejection fraction; CABG: Coronary artery bypass graft; CC: Cross-clamp; CPB: Cardiopulmonary bypass; eGFR: Estimated glomerular filtration rate; IQR: Interquartile range; CRP: C-reactive protein.

found to be significantly lower in the ESP group (p=0.008 and p=0.009, respectively). Likewise, the highest pain score reported in the same period was found to be significantly lower in the ESP group (p=0.016). In the ongoing days (24–48 h and 48–72 h), no difference was found for the highest pain score, opioid, and acetaminophen requirement in the groups (Table 2). While extubation time (median 420.0 versus 469.8 min, p=0.024) and ICU stay (median 20.5 versus 25 h, p=0.045) were shorter in the ESP group, hospital stay duration was similar (Fig. 1).

In the preoperative period, the NLR values were not different between the groups (p>0.05). These values peaked on the first day in the postoperative period and decreased in the next 2 days. The NLR values were found to be higher in all three measurement periods compared to the preoperative period, and these values were found to be significantly higher in the conventional group (p=0.019, p=0.046, and p=0.038, for NLR respectively, Table 2).

Discussion

In our study, the effects of USG-guided bilateral ESP block on surgery-induced inflammation were examined using NLR. It was found that NLR was significantly lower in the ESP group for three postoperative days. Also, the fact that the

Table 2. Analgesic consumption, pain scores, and neutrophil-lymphocyte ratio values

	Group C (n=55)	Group ESP (n=42)	p*
24 hours after extubation			
OME (mg), mean±SD	40.90±15.7	31.66±17.6	**0.008**
Acetaminophen (mg), mean±SD	1909.09±1058.8	1428.57±547.4	**0.009**
Highest reported pain score (VAS), median (IQR)	6 (5–7)	5 (4–7)	**0.016**
24-48th post extubation hours			
OME (mg), mean±SD	16.18±8.8	16.60±11.5	0.837
Acetaminophen (mg), mean±SD	689.09±558.16	685.71±572.0	0.977
Highest reported pain score (VAS), median (IQR)	3 (2–4)	2 (2–3)	0.674
Post extubation 48-72th hours			
OME (mg), mean±SD	11.45±8.1	9.04±6.7	0.124
Acetaminophen (mg), mean±SD	418.18±315.6	464.28±256.4	0.442
Highest reported pain score (VAS), median (IQR)	2 (1–3)	2 (1–2)	0.206
Preoperative NLR, mean±SD	2.72±1.0	2.96±1.1	0.465
PO 0th day NLR, mean±SD	21.54±10.7	17.22±7.3	**0.019**
PO 1st day NLR, mean±SD	10.98±6.8	8.92±3.0	**0.046**
PO 2nd day NLR, mean±SD	8.06±4.4	6.48±3.01	**0.038**

*: The independent samples t-test and Mann–Whitney U test were used for continuous variables. ESP: Erector spinae plane; OME: Oral morphine equivalent; SD: Standard deviation; VAS: Visual analog scale; IQR: Interquartile range; NLR: Neutrophil-lymphocyte ratio; PO: Postoperative.

ESP block reduced the postoperative opioid and acetaminophen consumption and significantly lowered pain scores in the first postoperative day after extubation was confirmed in our study. Additionally, our findings also revealed that the mechanical ventilation and ICU stay duration were significantly shorter in the ESP group. Complications such as infection, local anesthetic toxicity, pneumothorax, or hematoma that may be observed secondary to ESP block application were not noted in all patients. The results found in such a critical group of patients corroborated with previous studies showing that ESP block is a safe and effective technique for postoperative analgesia.[8,11,14]

Information regarding host immunity and inflammatory status can be obtained through the evaluation of neutrophil and lymphocyte counts and their ratios such as NLR obtained from the complete blood count. In cardiac surgery, neutrophilia and relative lymphopenia are used as prognostic markers for mortality.[15] A strong and statistically significant association between the first postoperative NLR value and 1-year mortality has been reported.[16] In parallel, patients with a 30-day mortality had a higher median NLR on the second postoperative day compared to patients without mortality.[17] Moreover, an increased NLR has been associated with the development of postoperative atrial fibrillation (AF) and acute kidney injury (AKI) after cardiac surgery.[16,18,19] The primary mechanism responsible for neutrophils is that stem cells increase neutrophil formation under the influence of growth factors.[20] Conversely, lymphocytopenia results from lymphocyte redistribution into the lymphatic organs due to the increase in catecholamine and cortisol levels and apoptosis.[21] Lymphocytes are mainly involved in specific immunity, and a decreased lymphocyte count is a feature of decreased immunity and is inversely proportional to inflammation. The combination of neutrophilia and lymphocytopenia in NLR increases the prognostic value compared to their individual effects, considering the complex nonlinear relationships between neutrophil and lymphocyte counts. These parameters obtained from routine blood tests have advantages in terms of cost-efficiency and time. When we examined the effect of ESP block and pain palliation on NLR in our study, we observed that the NLR values attained the highest levels in both groups in the first postoperative day and gradually decreased in the following periods. In all three measurement times, the NLR parameters were found to be significantly lower in the ESP group.

Surgical incision, dissection, nerve cut, stretching, or compression leads to perioperative pain. Some studies have revealed that acute postoperative pain can exacerbate this systemic inflammatory response and showed a positive correlation.[22,23] With peripheral inflammation induced by surgical trauma, some mediators, particularly interleukin-6 (IL-6), are released into the circulation and act on distant organs to stimulate the acute-phase response. This response induces acute-phase protein synthesis in the liver, neutrophil mobilization from the bone marrow,

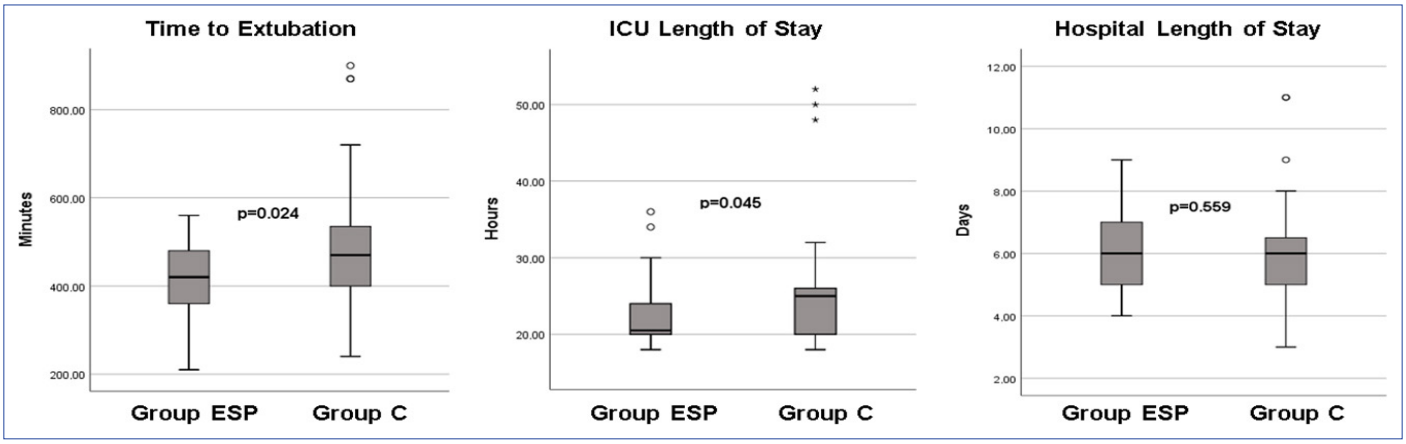

Figure 1. Extubation time and length of intensive care unit and hospital stay of the groups. The Mann–Whitney U test was used for the continuous variables (median, interquartile range [IQR]); the box plot represents data as median values (bold horizontal line) and IQR (box).
ICU: Intensive care unit; ESP: Erector spinae plane.

and altered T-lymphocyte differentiation.[4] Regional analgesia techniques block the transmission of nociceptive and inflammatory signals from the peripheral to the central nervous system and can prevent both peripheral and central pain sensitization, thus reducing postoperative pain sensation and inflammatory response following tissue injury.[5,24] In orthopedic surgeries, epidural block has been demonstrated to significantly reduce inflammatory mediators (IL-6 and CRP) and postoperative pain compared to patients treated with IV morphine.[22,25] Similarly, in cardiac surgery, ESP block employed as part of the ERAS program has been associated with lower postoperative CRP levels.[26] Our study contributes to the data supporting the use of ESP blocks in cardiac surgery patients, as it exhibited that ESP block is associated with lower inflammatory parameters and analgesic efficacy.

In addition to known surgical stress, CPB triggers the release of potent inflammatory mediators that elicit a major postoperative stress response that leads to a systemic inflammatory response-like syndrome.[27,28] Studies have revealed the relationship between inflammatory status, which is evaluated using NLR, and postoperative negative outcomes such as AF, delirium, and AKI in patients undergoing cardiac surgery.[16,29,30] Thus, the development of strategies to control the inflammatory response following cardiac surgery is currently the highlight of significant research efforts. Several techniques have been studied in clinical trials, including maintenance of hemodynamic stability, reducing CPB circuit exposure, and pharmacological and immunomodulatory agents. Others include minimized extracorporeal circulation system, off-pump coronary artery bypass surgery method, minimally invasive surgical technique, hemofiltration and leukocyte filter use during CPB, and some medical treatments.[31] However, while minimal extracorporeal circuits and leukocyte filter avoid most of the detrimental effects of standard CPB methods, these techniques warrant additional costs. Although ultrafiltration to remove liquid and low-molecular-weight substances from plasma has beneficial anti-inflammatory effects, especially in pediatric patients, hemofiltration seems to be less efficacious in adults.[31] Furthermore, not every patient is suitable for the off-pump or minimally invasive surgical technique. Corticosteroid use has not yet been fully elucidated because of its possible side effects and its net benefit has not yet been shown. Suggested medical treatments for anti-inflammation such as aprotinin, vitamins C and E, N-acetylcysteine, and mannitol do not have clear established effects. ESP block, aside from alleviating postoperative pain, can prevent inflammatory response induced by surgical stress. In our study, inflammatory parameters were lower in the ESP group and this decrease persisted for 3 days. This indicates that although the effect of local anesthetic administered with the ESP block has already expired, the initial anti-inflammatory effects of the block still continue. ESP block provides the clinical benefit of hitting two birds with one stone in cardiac surgery. In the postoperative period, two highly desirable conditions include quality analgesia and alleviation of the expected stress response. Admittedly, more studies are warranted to examine the effects on clinical outcomes.

One of the limitations of this study include the single-center, retrospective design. Another limitation is the lacking sensory test data determining the dermatomal distribution after the block. We deem that prospective studies with larger sample sizes are required to quantify inflammatory cytokines.

In conclusion, we believe that adding a preoperative ESP block to the strategies to alleviate the systemic inflammatory response after cardiac surgery will provide remarkable benefits. The fact that ESP block has exhibited inflammatory response reduction in addition to postoperative pain control may expand the indications for the block.

Disclosures

Ethics Committee Approval: The study was approved by The Ankara City Hospital No. 1 Clinical Research Ethics Committee (Date: 19/10/2022, No: E1-22-2982).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

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RESEARCH ARTICLE

Comparison of Modified and Conventional Ultrafiltration in Pediatric Patients Undergoing Open-Heart Surgery: Single-Center, Early Outcomes

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ABSTRACT

Objectives: The use of cardiopulmonary bypass (CPB) in pediatric patients during open-heart surgery is associated with excessive inflammation, fluid leakage, and end-organ dysfunction. To reduce these effects, various ultrafiltration (UF) techniques are utilized. In this study, we aimed to compare the effect and early outcomes of modified UF (MUF) and conventional UF (CUF) in infants undergoing pediatric cardiac surgery.

Methods: A total of 232 infants who underwent open-heart surgery with CPB between February 2018 and January 2020 were retrospectively reviewed. Fifty-six patients weighing ≤15 kg with a history of any UF technique use were included. Patients were stratified into CUF (n=23) and MUF (n=33) groups. Preoperative patient characteristics and intraoperative and postoperative outcomes were recorded.

Results: The MUF group had a lower patient size (height, weight, and body surface area), with no statistical difference. Intraoperative parameters (CPB and cross-clamp time) and prime solution components were similar between groups. MUF significantly shortened the mechanical ventilation (MV) time (p=0.048) in contrast to intensive care unit stay, which showed no significant difference.

Conclusion: In our series, we demonstrated that the MV duration was shorter in the MUF group, which is consistent with prior literature. Additionally, although the lower weight of the patients in the MUF group showed no statistical significance, early hemodynamic effect and low mortality in this group support the potential benefits of MUF. With its cost-efficiency and early benefits, MUF is an effective UF method with a good safety profile, especially in low-weight infants.

Keywords: Cardiopulmonary bypass, ultrafiltration, ventilator weaning

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Introduction

The use of cardiopulmonary bypass (CPB) is associated with remarkable inflammation, third-space fluid leakage, and end-organ dysfunction, particularly within the pediatric patient population.[1] To mitigate the adverse effects of inflammation and improve postoperative outcomes, various ultrafiltration (UF) techniques are routinely employed by several centers. The superiority among these UF methods remains a controversial discourse. The modified ultrafiltration (MUF) technique, introduced by Naik et al. [2] in 1991 for pediatric cardiac surgery patients, has been speculated to offer potential advantages over conventional ultrafiltration (CUF). While MUF use has gained popularity in pediatric cases, a consensus has not yet been reached regarding the specific patient profiles and protocols for its application. Our study aimed to investigate the impact of two different UF strategies on early phase outcomes in pediatric heart surgery cases.

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Methods

In the study, all patients (232 patients) who underwent cardiac surgery under CPB in the Department of Pediatric Cardiovascular Surgery at Diyarbakır Gazi Yaşargil Education and Research Hospital between February 2018 and January 2020 were retrospectively reviewed.

Infants weighing 15 kg or less who underwent any type of UF during open-heart surgery were included in the study. In this study, neonates were excluded owing to the more complex underlying cardiac pathologies and the predominant use of MUF in nearly all cases. Written informed consent was obtained from all parents of each patient prior to the study initiation. The Ethics Committee of our Hospital approved the research protocol (Date: 13.01.2023 No: 317). The study was conducted in accordance to the guidelines outlined in the Declaration of Helsinki. According to the applied filtration strategy, patients were divided into two groups: CUF (23 patients) and MUF group (33 patients). Conventional UF was conducted by passing the blood via a hemofilter (Fresenius, FX Paed) connected to the arterial line before the oxygenator during the warming phase. The ultrafiltered blood was returned to the patient through the venous line. MUF was employed after weaning from CPB, with a fluid withdrawal rate of 3–5 mL/kg/min for 10 min, considering the patient's overall fluid balance. During MUF, blood from the arterial line was passed through the oxygenator and heater, filtered through a hemofilter (Fresenius, FX Paed) by a roller pump, and returned to the right atrium via the venous line. The preoperative, intraoperative, and early hemodynamic parameters and postoperative outcomes of all patients were recorded.

Table 1. Patient characteristics and preoperative findings

Variables (%, median (IQR))	CUF group (n=23)		MUF group (n=33)		All patients (n=56)		p
	n	%	n	%	n	%	
Gender							0.47
Male	11	47.8	19	57.6	30	53.6	
Female	12	52.2	14	42.4	26	46.4	
Height (cm)	70 (65–75)		66 (64–74)		67 (64–74)		0.20
Weight (kg)	7.3 (5.7–9.0)		5.8 (5.3–7.8)		6.4 (5.4–8.4)		0.10
BSA (m^2)	0.38 (0.31–0.43)		0.32 (0.30–0.40)		0.35 (0.31–0.41)		0.12
Syndrome	4	17.4	3	9.1	7	12.5	0.36
Redo cardiac surgery**	0	0	1	3.0	1	1.8	0.30
Preoperative status							0.77
Active pneumonia	1	4.3	1	3.0	2	3.6	
Pulmonary hypertension	3	13.0	4	12.1	7	12.5	
Hypoxic spell	0	0	1	3.0	1	1.8	
Diagnosis							0.13
VSD	13	56.5	9	27.3	22	39.3	
CAVSD	4	17.4	10	30.3	14	25.0	
TOF	6	26.1	12	36.4	18	32.1	
TAPVR	0	0	2	6.1	2	3.6	
Laboratory findings							
Urea (mg/dL)	19 (15–23)		20 (15–23)		19 (15–23)		0.91
Creatinine (mg/dL)	0.40 (0.40–0.45)		0.41 (0.40–0.48)		0.41 (0.40–0.46)		0.49
Albumin (g/L)	42 (36–48)		43 (40–44)		43 (39–45)		0.73
AST (IU/L)	35 (30–44)		41 (31–44)		38 (30–44)		0.58
ALT (IU/L)	17 (13–27)		18 (14–28)		17 (13–27)		0.58
INR	1.17 (1.10–1.26)		1.25 (1.10–1.31)		1.21 (1.10–1.29)		0.23
Leukocyte (10^3/µL)	10.5 (8.9–12.9)		10.5 (8.1–14.7)		10.5 (8.4–13.2)		0.99
Hemoglobin (g/dL)	12.3 (10.9–13.2)		12.3 (11.9–14.7)		12.3 (11.4–13.6)		0.20
Platelet(10^3/µL)	360±93		378±110		370±103		0.42
CRP (mg/L)	2.0 (2.0–2.0)		2.0 (2.0–2.0)		2.0 (2.0–2.0)		0.59

**: Pulmonary banding operation. IQR: Inter quartile range; CUF: Conventional ultrafiltration; MUF: Modified ultrafiltration; BSA: Body surface area; VSD: Ventricular septal defect; CAVSD: Complete atrioventricular septal defect; TOF: Tetralogy of fallot; TAPVD: Total anomalous pulmonary venous return; AST: Aspartate transaminase; ALT: Alanine transaminase; INR: International normalized ratio; CRP: C-reactive protein.

Table 2. Intraoperative findings

Variables (%, med (IQR))	CUF group (n=23)		MUF group (n=33)		All patients (n=56)		p
	n	%	n	%	n	%	
Urgent surgery	1	4.3	5	15.2	6	10.7	0.18
Additional cardiac procedure							0.15
RV-PA conduit implantation	0	0	1	3.0	1	1.8	
Monocusp implantation	0	0	2	6.1	2	3.6	
Mitral valve repair	1	4.3	0	0	1	1.8	
Pulmonary banding	1	4.3	0	0	1	1.8	
CPB parameters							
Temperature (°C)	28 (28–32)		28 (28–28)		28 (28–28)		0.06
Cross clamp time (min)	92±35		91±29		92±31		0.06
CPB time (min)	128±42		141±44		136±44		0.39
Pre-CPB mean ABP (mmHg)	52±12		57±12		55±12		0.98
Lowest ABP during CPB (mmHg)	35 (30–40)		40 (35–40)		40 (35–40)		0.19
Post-CPB mean ABP (mmHg)	74±9		78±10		76±10		0.66
CPB fluid balance							
Prime volume of ES (ml)	150 (150–190)		150(145–150)		150 (150–160)		0.06
Prime volume of FFP (ml)	50 (30–85)		50 (39–70)		50 (31–70)		0.98
Prime volume of albumin (ml)	40 (30–50)		50 (35–50)		50 (35–50)		0.52
Cardioplegia volume (ml/kg)	40 (21–60)		20 (20–50)		30 (20–51)		0.14
Filtration volume (ml)	153±74		132±30		135±47		0.14
Negative fluid balance (ml)	80 (20–170)		100 (25–160)		95 (21–169)		0.59

IQR: Inter quartile range; CUF: Conventional ultrafiltration; MUF: Modified ultrafiltration; RV-PA: Right ventricle-pulmonary artery; CPB: Cardiopulmonary bypass; ABP: Arterial blood pressure; ES: Erythrocyte suspension; FFP: Fresh frozen plasma

Statistical Analysis

The Statistical Package for the Social Sciences software was used for the statistical analyses. For descriptive analyses, categorical variables were presented as frequencies (percentages), while normally distributed numerical variables were expressed as mean±standard deviation, and non-normally distributed numerical variables were presented as median (interquartile range). For group comparisons, the "chi-square Fisher's exact test" was used for the categorical variables, the "independent sample T-test" was used for normally distributed numerical variables, and the "Mann–Whitney U test" was used for non-normally distributed numerical variables. Statistical significance was set at a $p<0.05$.

Results

A total of 56 patients were included in the study, with 23 in the UF group and 33 in the MUF group. The patient characteristics such as height, weight, and body surface area (BSA) were relatively lower in the MUF group; however, no statistically significant difference was found between the two groups. Similarly, the presence of syndromes and a prior history of cardiac surgery did not reveal significant differences between the groups. No statistically significant differences were observed in terms of preoperative conditions (active pneumonia, pulmonary hypertension, and hypoxic spell) and diagnoses (ventricular septal defect, complete atrio-ventricular septal defect, tetralogy of Fallot [TOF], and total anomalous pulmonary venous return). Patient characteristics and preoperative findings are presented in Table 1.

In the intraoperative finding evaluation, there were no significant differences between the groups in terms of CPB parameters, cross-clamp time, CPB time, and arterial blood pressure (ABP) values. The amount of prime solution components (red blood cell suspension, fresh frozen plasma, and albumin) and cardioplegia volume were also similar between the groups. Moreover, the amount of filtration employed during CPB did not reveal a significant difference between the groups ($p>0.05$). The intraoperative parameters are detailed in Table 2.

In the postoperative finding evaluation, no statistically significant differences were observed between the groups in terms of vasoactive inotrope score and first-day laboratory results. When examining complications (such as wound infection rate, pacemaker implantation, sepsis, chylothorax, bleeding, and low cardiac output), no significant differences were found between the groups. The median mechan-

Table 3. Postoperative laboratory findings, complications and outcomes

Variables (%, med (IQR))	CUF group (n=23)		MUF group (n=33)		All patients (n=56)		p
	n	%	n	%	n	%	
Laboratory findings (1st day)							
Urea (mg/dL)	21 (18–27)		20 (16–29)		20 (16–28)		0.44
Creatinine (mg/dL)	0.40 (0.39–0.50)		0.42 (0.40–0.50)		0.41 (0.40–0.50)		0.72
Albumin (g/L)	34 (30–38)		34 (31–37)		34 (31–37)		0.96
AST (IU/L)	137 (116–224)		169 (120– 246)		148 (118–232)		0.34
ALT (IU/L)	20 (14–26)		21 (17–24)		21 (16–25)		0.58
INR	1.40 (1.31–1.58)		1.53 (1.41–1.66)		1.46 (1.35–1.64)		0.08
Leukocyte (10^3/µL)	15.9 (11.7–18.2)		14.8 (11.9–20.4)		15.8 (11.9–19.5)		0.98
Hemoglobin (g/dL)	11.6±1.7		11.3±1.5		11.4±1.6		0.95
Platelet(10^3/µL)	136 (107–188)		138 (92–186)		137 (99–188)		0.89
CRP (mg/L)	47±18		46±20		46±19		0.63
Vasoactive inotrope score	17±9.5		19.7±8.7		18.6±8.5		0.28
Complications							
Infection	3	13.0	2	6.1	5	8.9	0.37
Temporary pacemaker	0	0	1	3.0	1	1.8	0.30
Permanent pacemaker	2	8.7	2	6.1	4	7.1	0.71
Sepsis	1	4.3	1	3.0	2	3.6	0.79
JET	0	0	1	3.0	1	1.8	0.30
Gastrointestinal bleeding	1	4.3	0	0	1	1.8	0.18
Chylothorax	0	0	1	3.0	1	1.8	0.30
Re-exploration for bleeding	1	4.3	1	3.0	2	3.6	0.79
Low cardiac output	1	4.3	1	3.0	2	3.6	0.79
Peritoneal dialysis	1	4.3	1	3.0	2	3.6	0.79
MV time (hour)	24 (18–59)		14 (12–30)		20 (12–44)		0.048*
ICU stay (day)	5 (3–6)		5 (3–6)		5 (3–6)		0.91
Hospital stay (day)	13 (11–24)		15 (11–18)		15 (11–19)		0.65
Mortality	3 (13)		2 (6.1)		5 (8.9)		0.37

*: Statistically significant parameter. IQR: Inter quartile range; CUF: Conventional ultrafiltration; MUF: Modified ultrafiltration; AST: Aspartate transaminase; ALT: Alanine transaminase; INR: International normalized ratio; CRP: C-reactive protein; JET: Junctional ectopic tachycardia; MV: Mechanical ventilation; ICU: Intensive care unit

ical ventilation (MV) time was noted to be significantly shorter in the MUF group, with 14 (12–30) h, compared to the UF group (p:0.048). The median MV time was 24 (18–59) h in the UF group. The median time of intensive care unit stay was 5 (3–6) days in both groups, with no significant difference. The mortality rate was found to be 13% in the UF group and 6.1% in the MUF group, which was remarkable but with no statistically significant difference. Postoperative findings and outcomes are presented in Table 3.

Discussion

As the BSA decreases, the adverse effect of inflammation secondary to extracorporeal circulation increases.[3] In our study, parameters such as height, body weight, and BSA were lower in the MUF group, which was noteworthy. Accordingly, it can be inferred that the MUF group is composed of relatively more vulnerable patients, although with no statistical significance. When exploring intraoperative and postoperative outcomes, although the results of the UF group appear to be comparable to the MUF group, the MV time was shorter in the MUF group, with statistical significance.

Numerous studies[4,5] have reported similar results regarding MV time. In a prospective study by Talwar et al.[4] involving infants undergoing surgery for TOF, patients who received MUF exhibited lower peak airway pressure and shorter MV times. This could be attributed to MUF's potential to increase pulmonary compliance (both dynamic and static),[6] reduce lung injury,[7] and rapidly enhance pulmonary function in the early period.[8] Another experimental study performed on piglets[9] showed that MUF reduced pulmonary inflammation and pulmonary hypertension. Likewise, in another study involving single-ventricle patients, indirect indicators of pulmonary function, such as chest tube drainage and

pleural effusion, were significantly lower in patients who received MUF.[10] Considering all these findings, it can be concluded that the most discernible and early positive effect of MUF is on pulmonary function improvement.

Another notable effect of MUF is its contribution to early hemodynamics and myocardial function. Initially, Naik and colleagues[11] showed that MUF increases ABP. This effect has been elucidated in various studies over the years.[12–14] In a 2009 study by Yokoyama et al.,[13] they suggested that this effect could be attributed to Prostaglandin E2 (PGE-2) level reduction after MUF, leading to a more pronounced hemodynamic improvement in low-weight infants. Furthermore, many studies also suggested that MUF fosters myocardial function improvement.[15,16] In our study, although it can be postulated that the MUF group has demonstrated better performance when examining the ABP during and after CPB, the difference was not statistically significant. In a larger and more homogeneous series of patients, clearly observing and demonstrating the positive impact of MUF on hemodynamics and ventricular function might be possible, which corroborate with our clinical experiences and existing literature.

However, literature on the effect of MUF regarding postoperative bleeding is contradictory. Particularly, in publications from the 1990s when MUF gained popularity[2,17–19] it was highlighted that MUF reduced the requirement for postoperative blood replacement and the incidence of postoperative bleeding. However, in recent studies, this effect has not been consistently demonstrated. In fact, in a study by Abbas et al.,[20] it was revealed that MUF had a negative effect on thromboelastogram parameters, which improved again after protamine administration. In our series, no statistically significant difference was found in the reoperation rates due to bleeding between the two groups.

Fluid load reduction is another remarkable benefit of both UF methods. In our study, a similar negative fluid balance can be achieved with both techniques while maintaining comparable hemodynamic values. Considering early albumin, hematocrit, and ABP values, both methods seem to be equally efficacious in the reversal of hemodilution.

Limitations

The retrospective design and the limited number of patients are among the study's limitations. Moreover, the fact that the groups were not perfectly matched contributed to the study constraints.

Conclusion

In many centers, UF is routinely employed in pediatric open-heart surgery cases to reduce fluid overload and inflammatory mediators. In our series, it has been shown that MUF significantly shortened the MV time, consistent with the literature. While no significant differences were found among other parameters, the results of the MUF group, comprising more vulnerable patients with a lower BSA, support the potential benefits of MUF. In conclusion, MUF can be considered an easily applicable, low-cost, and potentially more efficacious method in certain aspects compared to CUF in infants undergoing pediatric cardiac surgery.

Disclosures

Ethics Committee Approval: The study was approved by The University of Health Sciences Gazi Yaşargil Training and Research Hospital Clinical Research Ethics Committee (Date: 13/01/2023, No: 317).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

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Authorship Contributions: Concept – F.Ö., O.D.; Design – F.Ö., O.D.; Supervision – F.Ö., O.D.; Materials – F.Ö., O.D.; Data collection &/or processing – F.Ö., O.D.; Analysis and/or interpretation – F.Ö.; Literature search – F.Ö.; Writing – F.Ö.; Critical review – F.Ö., O.D.

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RESEARCH ARTICLE

Effect of Previous Coronavirus Disease 2019 Infection on Patients Undergoing Open-Heart Surgery

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ABSTRACT

Objectives: This study aimed to evaluate the effects of previous coronavirus disease 2019 (COVID-19) infection on mortality, factors influencing mortality, and potential postoperative complications in on-pump cardiac surgery.

Methods: This single-center, retrospective, observational study included 233 adult patients who underwent on-pump cardiac surgery between June 2021 and February 2022. Patients with preoperative history of COVID-19 infection confirmed by nasopharyngeal swab polymerase chain reaction (PCR) test were compared to those without COVID-19 history.

Results: Patients' mean age was 60.12±11.26 years (range, 23–81 years), and 77.3% were male. The mean time from PCR positivity to surgery was 191.11±169.9 days (median, 108 days). No between-group differences were observed in anesthesia, cross-clamp time, pump time, operative time, extubation time, length of intensive care unit and hospital stay, or mortality (p>0.05). The post-COVID-19 group had higher rates of preoperative acute neurologic events and arrhythmias, pump lactate levels, and intraoperative inotropic scores (p<0.05). These factors were not associated with survival. Postoperative pneumothorax was more frequent in the post-COVID-19 group (p=0.002) and associated with longer length of hospital stay. No significant difference was observed in preoperative, postoperative, or changes in neutrophil/lymphocyte ratio (NLR) between groups.

Conclusion: Patients with and without COVID-19 history had similar outcomes after open-heart surgery. Nevertheless, the former had increased frequency of postoperative pneumothorax and prolonged length of hospital stay. Open-heart surgery seems safe after COVID-19. However, larger, prospective studies including inflammatory markers other than NLR are needed to further investigate the potential complications.

Keywords: Complications, neutrophil/lymphocyte ratio, open heart surgery, post-COVID-19

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Introduction

Coronavirus disease 2019 (COVID-19), which is caused by the SARS-CoV-2 virus, was first reported in Wuhan, China, in December 2019 and declared a pandemic by the World Health Organization on March 11, 2020. It spread rapidly worldwide, causing an unprecedented global health crisis.[1] Early in the pandemic, the presence of COVID-19 was associated with sevenfold higher mortality in patients undergoing heart surgery (24.5% vs. 3.5%, p<0.0001).[2] In addition, COVID-19 infection after open-heart surgery was associated with increased rates of pneumonia and mortality.[3]

At present, many patients with COVID-19 history are undergoing cardiac surgery. One study indicated that COVID-19 history in patients undergoing cardiothoracic surgery was not associated with significant mortality and morbidity, but 92.86% of these patients underwent beating-heart surgery.[4]

Regarding the safety of on-pump cardiac surgery in patients who recovered from COVID-19, literature data are limited. Thus, the present study aimed to determine the 30-day mortality rate and assess the factors influencing mortality and postoperative complications.

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Methods

This single-center, retrospective, observational study was approved by the Izmir Katip Celebi University Ataturk Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (decision number 0147, dated March 24, 2022). A total of 233 patients who underwent open-heart surgery between June 2021 and February 2022 in the cardiovascular surgery clinic were retrospectively evaluated. Patients with COVID-19 confirmed by polymerase chain reaction (PCR) test of a nasopharyngeal swab sample in the preoperative period were included in the post-COVID-19 group. Meanwhile, those without history of PCR-confirmed COVID-19 were included in the non-COVID-19 group. Patients who exhibited the clinical symptoms of COVID-19 and/or fever, who had a positive COVID-19 PCR test from a single nasopharyngeal swab sample 48 h before surgery, and who underwent off-pump (beating heart) surgery were excluded. The data were obtained from the hospital information system, patient history, and patient records.

Data including demographic data, European System for Cardiac Operative Risk Evaluation II score, risk factors, intraoperative variables, postoperative clinical outcomes, complications (pneumothorax, acute kidney injury, thrombosis, coagulopathy, acute neurological event, revision surgery, bleeding), length of hospital stay, length of intensive care unit (ICU) stay, and 30-day mortality were noted. Preoperative and postoperative 24-h leukocyte, lymphocyte, and neutrophil levels were determined, and the neutrophil/lymphocyte ratio (NLR) was calculated.

With regard to the post-COVID-19 group, the time from COVID-19 infection to surgery and the clinical presentation of COVID-19 were also recorded. Renal failure was defined according to Kidney Disease: Improving Global Outcomes staging. The inotrope score (IS) was determined using the following formula: dopamine dose (mcg/kg/min)+dobutamine dose (mcg/kg/min)+100×epinephrine dose (mcg/kg/min).[4] This study was conducted in accordance with the tenets of the 1964 Declaration of Helsinki and its later revisions.

Statistical Methods

Statistical analysis was performed using IBM SPSS version 26 software. Categorical variables were expressed as number and percentage, whereas continuous variables as mean, standard deviation, range, median, and interquartile range (25^{th}–75^{th} percentile). Pearson's chi-square and Fisher's exact tests were used for comparison of categorical variables between groups. The Mann–Whitney U test was used for pairwise comparisons of continuous variables because the data were not normally distributed (Kolmogorov–Smirnov $p<0.05$). Univariate logistic regression analysis was used to evaluate variables thought to be associated with mortality. Statistical significance was considered at $p<0.05$.

Results

A total of 233 patients (61 in the post-COVID-19 group, 172 in the non-COVID-19 group) who underwent on-pump open-heart surgery were evaluated. The mean age was 60.12±11.26 years (range, 23–81 years), and 77.3% of patients were male. The mean ejection fraction was 53.57%±10.41%. The mean length of ICU and hospital stay was 4.38±3.99 days (range, 2–40 days) and 15.63±6.63 days (range, 3–54 days), respectively.

In the post-COVID-19 group, the clinical course of COVID-19 infection was as follows: nine patients (14.8%) were asymptomatic, 40 patients (65.6%) were mildly symptomatic requiring home care, 10 patients (16.4%) had moderate symptoms requiring hospitalization, and 2 patients (3.3%) had severe symptoms requiring ICU admission. Among all patients, 81.7% had received at least one dose of COVID-19 vaccine, whereas 18.3% were unvaccinated. No statistically significant difference was observed in the vaccination rate between the two groups (Table 1).

The mean number of days from PCR positivity to surgery was 191.11±169.9 days, and the median interval was 108 days (range, 8–523 days). The post-COVID-19 group had significantly higher preoperative acute neurological events and arrhythmias than the non-COVID-19 group ($p=0.037$ and $p=0.012$, respectively). Meanwhile, the non-COVID-19 group had higher frequency of coronary artery bypass graft (CABG) surgery compared with the post-COVID-19 group. Most cases (89.5%) were elective, whereas the remaining 10.5% were emergency surgeries. Table 1 shows a comparison of preoperative characteristics, demographic data, and surgical types.

The 30-day mortality rate was 3.3% in the post-COVID-19 group and 2.9% in the non-COVID-19 group ($p>0.05$). Table 2 shows a comparison of mortality rates and cause of death.

No difference was observed in the anesthesia time, cross-clamp time, pump time, or operative time between groups ($p>0.05$). However, the post-COVID-19 group had significantly higher pump lactate levels and intraoperative IS than the non-COVID-19 group ($p=0.000$ and $p=0.037$, respectively). Table 3 shows the intraoperative data.

The prevalence of postoperative pneumothorax was higher in the post-COVID-19 group than in the non-COVID-19 group ($p=0.002$) (Table 4). Patients in the post-COVID-19 group who developed pneumothorax had longer hospital stays, and the frequency of pneumothorax was higher in patients admitted to the ICU ($p<0.05$) (Table 5).

Table 1. Preoperative characteristics, demographic data, and types of operation

	Post-COVID-19 group (n=61)		Non-COVID-19 group (n=172)		X^2/Z	p
	n	%	n	%		
Age (years)	61	20.5	60.5	14	–0.085	0.932
Sex (male)	42	68.9	138	80.2	3.319	0.068
EuroSCORE	2	1.28	2	1.58	–0.648	0.517
EF	55	10	60	10	–0.778	0.437
BMI (kg/m^2)	28 (3.5)		27.4 (4)		–0.134	0.893
DM	24	39.3	68	39.5	0.001	0.979
Smoking	25	41	92	53.5	2.817	0.093
HT	39	63.9	106	62.4	0.048	0.826
COPD	8	13.1	32	18.8	1.022	0.312
Acute neurological event	8	13.1	8	4.7	5.044	**0.037**
Pneumothorax	2	3.3	–	–	5.410	0.068
At least 1 dose of vaccine	53	86.9	72	78.3	1.825	0.177
Arrhythmia	20	32.8	30	17.4	6.291	**0.012**
NLR	2.36 (1.89)		2.48 (1.63)		–0.737	0.461
PaO_2 (mmHg)	92 (25.65)		90.5 (23.23)		–2.797	0.056
Lactate (mmol/L)	1.2 (0.6)		1.1 (0.6)		–1.341	0.180
Surgery type						
Emergency	6	9.8	18	10.5	0.019	0.890
Elective	55	90.2	154	89.5		
Surgical procedure						
CABG	35	57.4	123	71.5	4.122	**0.042**
If CABG, no. of vessels	3	1	3	1	–0.513	0.608
AVR	9	14.8	12	7	3.321	0.068
MVR	6	9.8	17	9.9	0.000	0.991
AVR+MVR	1	1.6	5	2.9	0.288	1.000
Valve+CABG	4	6.6	10	5.8	0.044	0.763
Ascending aortic aneurysm	6	9.8	8	4.7	2.143	0.205
Aortic dissection	3	4.9	4	2.3	1.039	0.382

EuroSCORE: European System for Cardiac Operative Risk Evaluation; EF: Ejection fraction; BMI: Body mass index; DM: Diabetes mellitus; HT: Hypertension; COPD: Chronic obstructive pulmonary disease; NLR: Neutrophil/lymphocyte ratio; PaO_2: Arterial partial pressure of oxygen; CABG: Cardiac artery bypass graft; AVR: Aortic valve repair; MVR: Mitral valve repair

Table 2. Rates and causes of mortality

	Post-COVID-19 group (n=61)		Non-COVID-19 group (n=172)		Total		X^2	p
	n	%	n	%	n	%		
Mortality								
Yes	2	3.3	5	2.9	7	3	0.021	1.000
No	59	96.7	167	97.1	226	97		
Cause of death								
MODS	2	100	3	60	5	71.4	1.12	1.000
ARDS	0	0	2	40	2	28.6		

MODS: Multiorgan dysfunction syndrome; ARDS: Acute respiratory distress syndrome

Table 3. Intraoperative findings

	Post-COVID-19 group (n=61)	Non-COVID-19 group (n=172)	X^2/Z	p
Anesthesia time (min)	240 (75)	240 (85)	–1.091	0.275
Operative time (min)	220 (70)	220 (85)	–0.520	0.603
Pump time (min)	82 (48.5)	80 (36.5)	–0.946	0.344
Cross-clamp time (min)	47 (35.5)	44 (22.5)	–1.713	0.087
Total blood loss (mL)	400 (250)	400 (200)	–1.364	0.172
IS	10 (15)	5 (13.5)	–2.086	**0.037**
Pump PO_2 (mmHg)	271 (68.5)	270 (58.25)	–0.140	0.889
Pump lactate (mmol/L)	1.3 (1.05)	1 (0.6)	–3.510	**0.000**

IS: Inotrope score; PO_2: Partial pressure of oxygen

Table 4. Postoperative data and complications

	Post-COVID-19 group (n=61)	Non-COVID-19 group (n=172)	X^2/Z	p
Extubation time (h)	9 (3.75)	9.15 (4.28)	–1.078	0.281
Prolonged weaning (>24 h)	7 (11.5)	18 (10.6)	0.037	0.848
Length of ICU stay (days)	4 (2)	3 (2)	–1.366	0.172
Length of hospital stay (days)	15 (5)	15 (7)	–1.066	0.286
AKI	12 (19.7)	30 (17.6)	0.124	0.725
Pneumothorax	12 (19.7)	10 (5.9)	9.907	**0.002**
Pneumonia	4 (6.6)	6 (3.5)	0.994	0.298
Arrhythmia	19 (31.1)	41 (24.1)	1.154	0.283
Acute neurological event	2 (3.3)	2 (1.2)	1.166	0.285
Revision surgery	8 (13.1)	27 (15.9)	0.267	0.605
Postoperative bleeding	13 (21.3)	54 (31.8)	2.382	0.123
PO_2 (mmHg)	101 (42)	102 (45.78)	–2.208	0.067
Lactate (mmol/L)	1.6 (1.4)	1.4 (1.2)	–1.691	0.091
Hematocrit (%)	29.5 (4.75)	29 (5.15)	–0.318	0.751
NLR	19 (17.13)	16.51 (12.86)	–1.468	0.142

h: Hour; ICU: Intensive care unit; AKI: Acute kidney injury; PO_2: Partial pressure of oxygen; NLR: Neutrophil/lymphocyte ratio

In univariate logistic regression analysis of variables that may affect survival in the post-COVID-19 group, NLR was not a significant predictor of survival (Table 6).

Postoperative NLR was significantly higher than preoperative NLR in both groups ($p<0.05$). When the post-COVID-19 and non-COVID-19 groups were compared, there was no statistically significant difference between groups in terms of preoperative and postoperative NLR or change in NLR ($p>0.05$) (Table 7). Figure 1 shows the mean preoperative and postoperative NLR of all patients and both groups. Figure 2 shows the difference between preoperative and postoperative NLR in both groups.

Discussion

In this study, similar clinical outcomes and mortality rates were observed in patients undergoing on-pump open-heart surgery with and without history of COVID-19 infection. However, the post-COVID-19 group had more frequent postoperative pneumothorax, and those who developed pneumothorax postoperatively had longer hospital stays. Moreover, the post-COVID-19 group had higher rates of acute neurological events and arrhythmia preoperatively and increased intraoperative IS and pump lactate levels. The results showed that the inflammatory marker NLR and postoperative changes in NLR were not associated with mortality.

A study comparing COVID-19-positive patients and those without COVID-19 infection undergoing open-heart surgery early in the pandemic showed that the former had longer length of ICU stay and higher mortality than the latter. [2] In the same study, comparison of patients with preoperative COVID-19 and those without COVID-19 history revealed

Table 5. Distribution of preoperative and demographic variables in recovered COVID-19 patients with and without postoperative pneumothorax

Pneumothorax	No (n=12)	Yes (n=49)	X^2/Z	p
Vaccination	41 (83.7)	12 (100)	2.255	0.337
Sex				
Female	16 (32.7)	3 (25)	0.263	0.737
Male	33 (67.3)	9 (75)		
Age (years)	61 (21.5)	62.5 (15.25)	–0.5	0.617
EF	60 (10)	55 (8.75)	–0.5	0.616
EuroSCORE	4 (4.27)	1.75 (2.8)	–1.52	0.127
Smoking	22 (44.9)	3 (25)	1.578	0.328
COPD	6 (12.2)	2 (16.7)	0.165	0.650
Obesity	13 (26.5)	3 (25)	0.012	1.000
BMI	27 (4)	28 (3.75)	–0.58	0.559
COVID-19 severity				
Asymptomatic at home	6 (12.2)	3 (25)	1.247	0.361
Symptomatic at home	35 (71.4)	5 (41.7)	3.782	0.088
Intensive care admission	0 (0)	2 (16.7)	8.444	**0.036**
Inpatient admission	8 (16.3)	2 (16.7)	0.001	1.000
Days from PCR positivity to surgery	97 (293.5)	220.5 (384)	–1.45	0.147
Preoperative pneumothorax	1 (2)	1 (8.3)	1.204	0.357
Change in NLR	15.67 (19.96)	15.18 (8.77)	–0.4	0.690
Surgical procedure				
CABG	28 (57.1)	7 (58.3)	0.006	0.940
If CABG, no. of vessels	3 (2)	3 (1)	–0.93	0.352
AVR	7 (14.3)	2 (16.7)	0.043	1.000
MVR	5 (10.2)	1 (8.3)	0.038	1.000
AVR+MVR	1 (2)	0 (0)	0.249	1.000
Valve+CABG	2 (4.1)	2 (16.7)	2.492	0.170
Aneurysm	6 (12.2)	0 (0)	1.63	0.588
Dissection	3 (6.1)	0 (0)	0.773	1.000
Postoperative outcomes				
Duration of MV (h)	9 (3.75)	9 (3.75)	–0.05	0.956
Length of ICU stay (days)	3 (2)	4.5 (2.75)	–1.05	0.294
Length of hospital stay (days)	14 (5.5)	18 (6)	–2.28	**0.023**

EF: Ejection fraction; EuroSCORE: European System for Cardiac Operative Risk Evaluation; COPD: Chronic obstructive pulmonary disease; BMI: Body mass index; PCR: Polymerase chain reaction; NLR: Neutrophil/lymphocyte ratio; CABG: Coronary artery bypass graft; AVR: Aortic valve repair; MVR: Mitral valve repair; MV: Mechanical ventilation; ICU: Intensive care unit

no significant difference in terms of mortality.[2] In the present study, the 30-day mortality rate in the post-COVID-19 group was similar to that in the non-COVID-19 group (3.3% vs. 2.9%, respectively, p>0.05). Similarly, in another study that evaluated cardiothoracic surgery in post-COVID-19 and non-COVID-19 patients, previous COVID-19 infection was not associated with mortality. However, this study evaluated 35 post-COVID-19 patients, of whom 28 underwent CABG and only two had on-pump cardiac surgery. The complications and survival rates were similar in both groups.[5] In another study, cardiac surgery could be performed safely in patients who had preoperative COVID-19 infection, especially after asymptomatic or clinically mild infection. This study demonstrated the early effects of the pandemic, with a mean of 46.3 days from COVID-19 PRC test to surgery.[6] In the present study, the mean time from PCR positivity to surgery was 108 days (range, 8–523 days). Thus, our results reflect the later effects of the pandemic. There are few data in literature on whether on-pump cardiac surgery can be safely performed in patients who have recovered from COVID-19, making our study an important contribution to literature.

When complications were compared between groups in the present study, the results showed that postoperative pneumothorax occurred more frequently in the post-COVID-19 group than in the non-COVID-19 group (19.7%

Table 6. Results of univariate logistic regression analysis of factors that may be associated with mortality in the post-COVID-19 group

Post-COVID group	B	p	OR	95% CI	
Postoperative pneumothorax	–18.046	0.999	0.000	0.000	
Preoperative acute neurological event	–17.964	0.999	0.000	0.000	
Preoperative arrhythmia	0.744	0.606	2.105	0.125	35.5
Postoperative arrhythmia	0.823	0.568	2.278	0.135	38.469
Preoperative NLR	–0.001	0.995	0.999	0.770	1.297
Postoperative NLR	–0.220	0.240	0.803	0.556	1.158
Preoperative lactate	–0.584	0.672	0.557	0.037	8.365
Pump lactate	–7.988	0.152	0.000	0.000	18.706
Postoperative lactate	–3.597	0.166	0.027	0.000	4.452
Days from PCR positivity to surgery	0.001	0.803	1.001	0.993	1.009

OR: Odds ratio; CT: Computed tomography; NLR: Neutrophil/lymphocyte ratio; PCR: Polymerase chain reaction

Table 7. Preoperative and postoperative values and postoperative changes in NLR

	Post-COVID-19 group		Non-COVID-19 group		
	Median (IQR)	p^1	Median (IQR)	p^1	p^2
Preoperative NLR	2.36 (1.89)	**<0.001**	2.48 (1.63)	**<0.001**	0.461
Postoperative NLR	19 (17.13)		16.51 (12.86)	0.142	
Change in NLR	15.67 (17.28)		13.76 (11.44)	0.209	

P^1: Preop vs. postop; P^2: Post-COVID-19 vs. non-COVID-19 groups. The preoperative to postoperative change in NLR was statistically significantly in both groups (p1<0.05). Postoperative NLR was significantly higher than preoperative NLR. Both groups did not differ significantly in terms of preoperative, postoperative, or change in NLR (p2>0.05). NLR: Neutrophil/lymphocyte ratio; IQR: Interquartile range

vs. 5.9%) (p=0.002). However, this did not have a significant impact on survival, despite a significantly longer mean length of hospital stay in recovered COVID-19 patients with postoperative pneumothorax. Other complications occurred at similar rates in both groups. One study indicated that 7.4% of post-COVID-19 patients develop pneumomediastinum, and 8.6% develop pneumothorax.[7]

Although many case reports cite an increase in the rate of pneumothorax in post-COVID-19 patients,[8–10] data on this finding after cardiac surgery are limited. In their study evaluating the effect of COVID-19 infection on cardiac surgery outcomes, Thomas et al.[5] evaluated preoperative chest computed tomography (CT) findings and detected emphysematous and fibrotic changes in 2.85% and 42.8% of patients, respectively. In our clinic, routine chest CT was not performed in all patients who recovered from COVID-19. Therefore, we do not have clear data regarding preoperative emphysematous and fibrotic findings in our patients. Of course, many factors related to the surgical technique and anesthesia administration in the preoperative, perioperative, and postoperative period can lead to respiratory complications (including pneumothorax) in patients undergoing heart surgery.[11] It is difficult to say whether this finding is associated with previous COVID-19 infection. However, the increase in postoperative pneumothorax independent of surgical procedure in patients with COVID-19 history may be a late complication. Moreover, the longer hospital stays in these patients suggest that this finding warrants further investigation.

The long-term effects of COVID-19 are a result of endothelial dysfunction characterized by macro- and microvascular thrombosis secondary to inflammation, especially in the cardiovascular and respiratory system.[7,11,12] Previous COVID-19 infection has been proven to be a high-risk factor for cardiovascular problems (especially cardiac rhythm disorders) and cerebrovascular events.[7,13] This is supported by the higher rates of preoperative arrhythmia and neurological events in the post-COVID-19 group in the present study.

The NLR changes in both groups were compared to evaluate a possible relationship between endotheliopathy and increase in pneumothorax. However, this parameter was not found to be associated with pneumothorax development or survival.

According to the results of a cohort study involving approximately 3,000 patients, a postoperative increase in NLR in patients undergoing cardiac surgery was associated with

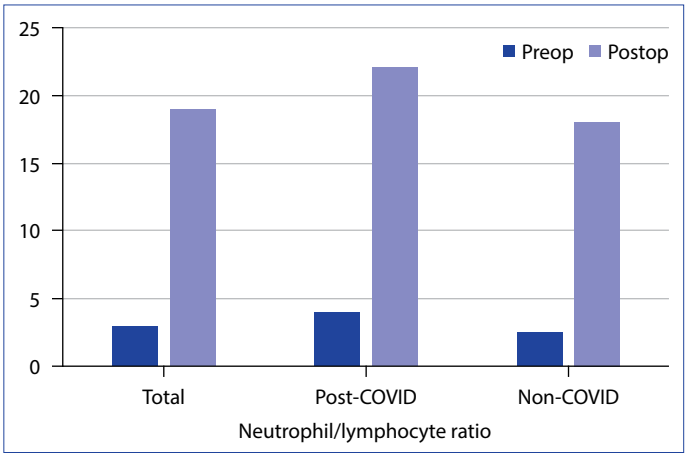

Figure 1. Preoperative and postoperative neutrophil/lymphocyte ratio (NLR).

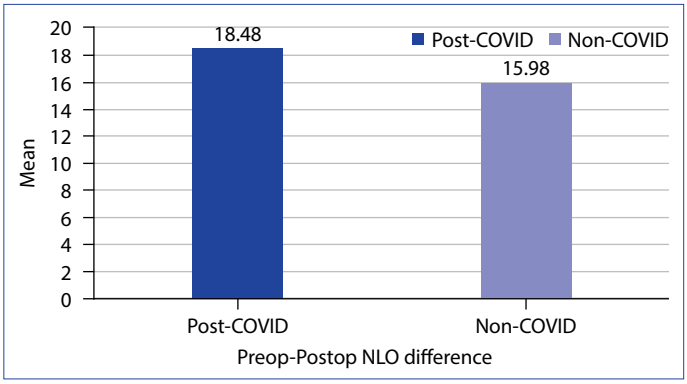

Figure 2. Preoperative to postoperative change in neutrophil/lymphocyte ratio (NLR) in the post-coronavirus disease 2019 (COVID-19) and non-COVID-19 groups.

higher mortality and longer hospital and ICU stay, and was found to be an independent prognostic biomarker.[14] In the present study, postoperative NLR was significantly higher than preoperative NLR in both groups ($p<0.05$). However, NLR and its change had no effect on survival in either group. This finding is inconsistent with literature and may be related to our small patient series.

Early-onset hyperlactatemia after cardiac surgery is related to many common hypoxic and non-hypoxic factors associated with major morbidity and mortality (e.g., drug therapy, cardioplegia, cardiopulmonary bypass, and hypothermia).[15] In one study, a threefold or greater increase in baseline intraoperative lactate level in adult cardiac surgery was found to be an important determinant of length of ICU stay, postoperative renal failure, and mortality.[16] Another study of on-pump CABG surgery showed that the risk of postoperative complications increased in patients with elevated lactate levels after high IS.[17] In the present study, pump lactate levels and IS were higher in the post-COVID-19 group than in the non-COVID-19 group but did not have a significant effect on survival. Studies with larger sample sizes may elucidate the clinical significance of this finding.

Limitations

This study was retrospective. Therefore, the findings must be supported by prospective randomized controlled studies. The small patient sample may also limit the generalization of the results reported here. In addition, NLR was the only inflammatory marker that could be evaluated in this study. The results of laboratory tests such as serum fibrinogen, D-dimer, C-reactive protein, and procalcitonin were not available. The ability to perform advanced preoperative imaging in patients who recovered from COVID-19 may provide guidance regarding potential postoperative complications.

Conclusion

Patients with and without a history of COVID-19 had similar outcomes after open-heart surgery. However, the increased frequency of postoperative pneumothorax and the prolonged length of hospital stay in post-COVID-19 patients who developed pneumothorax are noteworthy. Open-heart surgery seems safe after COVID-19. Nevertheless, larger, prospective studies including inflammatory markers other than NLR are needed to further investigate the potential complications.

Disclosures

Ethics Committee Approval: The study was approved by The İzmir Katip Çelebi University Non-interventional Clinical Research Ethics Committee (Date: 24/03/2022, No: 0147).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

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RESEARCH ARTICLE

Role of Tracheostomy in Pediatric Patients Who Underwent Heart Surgery: A Single-Center Experience

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ABSTRACT

Objectives: This study aimed to review the characteristics and outcomes of children with congenital heart disease requiring tracheostomy after cardiac surgery.

Methods: Medical records of 65 out of 2814 consecutive patients who required tracheostomy after congenital heart surgery between March 2018 and March 2023 were retrospectively reviewed. Outcomes such as hospital survival, long-term survival, and weaning from positive pressure ventilation were elucidated.

Results: During the 5-year period, a total of 65 of 2814 (2.3%) patients required tracheostomy in the pediatric intensive care unit after surgery. The median patient age was 5 (range, 0.6–24) months and the median weight was 4.3 kg (range, 3.3–11). A total of 23 (35.5%) patients demonstrated a single-ventricle physiology while 42 (64.5%) patients manifested with biventricle physiology. A total of 11 (16.9%) patients were syndromic, including Down syndrome in 6 patients, Di George syndrome in 3 patients, and Williams syndrome in 2 patients. In the whole cohort (65 patients), the mean time to tracheostomy from cardiac surgery was 30±16 days. In-hospital mortality was noted in 20 of the patients (30.8%) who underwent tracheostomy. Twenty-six patients (40%) were decannulated and discharged without a tracheostomy, and 14 patients (22%) were discharged with a tracheostomy cannula and home-type mechanical ventilator (HMV).

Conclusion: Tracheostomy is a viable option for pediatric patients with prolonged mechanical ventilation after heart surgery for congenital heart disease. It creates an opportunity to discharge patients on HMV, if repeated attempts of extubation and decannulation fail, albeit with potential risks.

Keywords: Mechanical ventilation, pediatric intensive care unit, tracheostomy

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Introduction

Congenital heart disease (CHD) may manifest as part of a genetic syndrome, which affects multiple organ systems; however, it can also present as an isolated defect that can potentially affect other organ systems as a result of pathophysiology or due to complications during the treatment course. Pediatric patients with congenital heart defects are already at risk of respiratory problems, as most of these patients are born with immature lungs and have syndromes with facial and airway deformities (such as 22q11 deletion syndrome; trisomy 21; and coloboma, heart defect, choanal atresia, retarded growth and development, and ear deformity; and vertebral defects, anal atresia, cardiac defects, tracheo-esophageal fistula, renal anomalies, and limb abnormalities), which can predispose affected children to airway problems, pulmonary artery or vein anomalies, aortopulmonary collaterals or pulmonary hypertension, immune deficiencies, and recurrence of pulmonary infections. Patients undergoing heart surgery are prone to respiratory complications preoperatively, perioperatively, and postoperatively not only because of the predisposing factors, but also due to possible postoperative complications such as low cardiac output syndrome, prolonged mechanical circulatory support, pulmonary edema, neurological disorders, hospital-acquired infections, and di-

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aphragm or vocal cord paralysis, which may increase the risk of prolonged mechanical ventilatory support.

Prolonged mechanical ventilation after surgery for CHD is common and approximately 10% of children remained intubated after 7 days.[1,2] Most of these children will be eventually extubated; however, a small subset will require further intervention such as tracheostomy to facilitate long-term mechanical ventilation and possibly home ventilation.[3] After cardiac surgery, children are at an even higher risk of morbidity, with one study finding showing that children undergoing cardiac surgery have a fivefold risk of dying after tracheostomy than those without surgery.[4]

The indication for tracheostomy is multi-factorial even with or without the presence of a residual cardiac defect; however, prolonged mechanical ventilation and repeated failed extubation are the main indications documented in the patient charts. Additionally, the timing of tracheostomy is highly variable among studies.

This study aimed to determine the evolution of the decision-making process for our institution in terms of indications, timing, and management outcomes for the pediatric heart surgery patients who require long-term mechanical ventilatory support and who are candidates for tracheostomy.

Methods

A retrospective review of the medical records of 65 consecutive patients who required tracheostomy after congenital heart surgery between March 2018 and March 2023 was conducted. Data were retrospectively collected from the patient's previous hospital records. The medical records of the demographic characteristics, cardiac diagnosis, operative procedures, presence of genetic syndromes, and comorbidities were documented. The institutional ethics committee approved the study on 11/29/2022 (E-28001928-604.01.01) and was conducted in accordance with the principles of the Declaration of Helsinki. Since the trachea and airway of children with CHD are small, immature, and sometimes present with anomalies due to genetic disorders, tracheostomy cannulas are surgically inserted in all patients. The exclusion criteria included patients who underwent intervention secondary to congenital heart anomaly without undergoing surgery.

Patients were accepted as candidates for tracheostomy after failure of three elective extubation attempts, and the indications for tracheostomy included prolonged intubation, tracheobronchomalacia, tracheal and bronchial stenosis, vocal cord paralysis, hemodynamic instability, and diaphragmatic paralysis.

Surgical Technique

A horizontal skin incision is made 1–1.5 cm below the carotid cartilage in the anterior midline of the neck. After extending the incision into the platysma muscle, the sternohyoid and sternothyroid muscles are laterally retracted. The second and third tracheal rings are then determined. After the incision between the second and third ring, the tracheostomy tube is then placed. Thereafter, the tube is connected to the anesthesia circuit and confirmed using end-tidal CO_2.

Statistical Analysis

Continuous variables were reported as the mean±standard deviation for normally distributed variables and as the median (range) for non-normally distributed variables. Categorical variables were reported as n (%). For all statistical analyses, the IBM SPSS Statistics Software 21 (SPSS Inc., Chicago, IL, USA) was used.

Results

During the 5-year period, a total of 65 out of 2814 (2.3%) patients required tracheostomy in the pediatric intensive care unit (ICU) after a pediatric cardiac operation, and the male/female ratio was 32 out of 33. The median age of the patients was 5 (range, 0.6–24) months and the median weight of the patients was 4.3 (range, 3.3–11) kg. Twenty-three (35.5%) patients had a single-ventricle physiology while 42 (64.5%) patients presented with biventricle physiology. A total of 11 (16.9 %) patients were syndromic, including Down syndrome in 6 patients, Di-George syndrome in 3 patients, and Williams syndrome in 2 patients. A total of 23 patients (35%) required preoperative mechanical ventilation and 26 patients (40%) had a history of prior hospitalization. The median cardiopulmonary bypass and aortic cross-clamp times were 83 min (range, 59–106) and 144 min (range, 103–194), respectively. Antegrade cerebral perfusion was used for a median of 20 min (range, 16–28) in 17 patients (Table 1).

Sternal closure was delayed in 42 patients (64.6%) with a mean of 4.3±2.9 days. Owing to mediastinitis or delayed sternal closure in six patients (9.2%), vacuum-assisted closure therapy was performed. Sudden cardiac arrest occurred in nine patients (9.2%). Of all patients, 22 out of 65 (34%) required postoperative extracorporeal membrane oxygenation (ECMO) support due to cardiopulmonary resuscitation or low cardiac output. In the early postoperative period, left diaphragm plication was conducted in 15 patients and bilateral diaphragmatic plication was performed in three patients due to diaphragmatic paralysis. Renal replacement therapy with peritoneal dialysis was performed in 38 (58.4%) patients. Chylothorax developed in 21 patients (32.3%), and thoracic duct ligation was performed in five patients. Pneumonia and sepsis (confirmed through microbiological cultures) were observed in 51 (78.4%) and 16 (24.6%) patients, respectively, and the medical therapy was administered according to the antibiograms (Table 1).

Table 1. Patient characteristics

Variables (%, mean±SD, median (range))	All patients (n=65)	
	n	%
Gender		
Male	32	49.2
Female	33	50.8
Age (months)	5 (0.6–24)	
Weight (kg)	4.3 (3.3–11)	
Syndrome	11	16.9
Down	6	9.2
Di-George	3	4.6
Williams	2	3.1
Cardiac physiology		
Univentricular heart	23	35.3
Biventricular heart	42	64.7
Preoperative status		
Hospitalization	26	40
Need of MV	23	35
Type of surgery		
Palliative	31	47.7
Corrective	34	52.3
CC time (min)	83 (59–106)	
CPB time (min)	144 (103–194)	
ASP time (min)	20 (16–28)	
Vasoactive inotrope score	21.4±9.8	
Complications		
Delayed sternal closure	42	64.6
Sternal closure time (day)	4.3±3.9	
VAC therapy	6	9.2
Sudden cardiac arrest	9	13.8
ECMO support	22	33.8
Diaphragmatic paralysis	18	27.5
Peritoneal dialysis	38	58.4
Chylothorax	21	32.3
Neurological event	9	13.8
Pneumonia	51	78.4
Sepsis	16	24.6

SD: Standard deviation; MV: Mechanical ventilation; CC: Cross clamp; CPB: Cardiopulmonary bypass; ASP: Antegrade cerebral perfusion; VAC: Vacuum assisted closure; ECMO: Extra Corporeal Membrane Oxygenator

Table 2. Summary of underlying congenital heart defects

Variables (%)	All patients (n=65)	
	n	%
Univentricular heart	23	35.3
Complex univentricular defects	9	13.8
Borderline LV	3	4.6
HLHS	7	10.8
Tricuspid atresia	2	3.1
IVS-PA	3	4.6
Biventricular Heart	42	64.7
TOF-CAVSD	1	1.5
VSD-PA	7	10.8
DORV	1	1.5
Vascular ring	2	3.1
Aortic stenosis	1	1.5
Arcus hypoplasia	5	7.7
Transposition of great arteries	7	10.8
Aortopulmonary window	2	3.1
CAVSD	3	4.6
Tetralogy of fallot	2	3.1
LVOTO	1	1.5
TOF-absent pulmonary valve	2	3.1
VSD	2	3.1
Pulmonary insufficiency	1	1.5
TAPVR	2	3.1
Shone's complex	2	3.1
Other	1	1.5

LV: Left ventricle; HLHS: Hypoplastic left heart syndrome; IVS: Intact ventricular septum; PA: Pulmonary atresia; DORV: Double outlet right ventricle; CAVSD: Complete atrioventricular septal defect; LVOTO: Left ventricular outflow tract obstruction; TOF: Tetralogy of fallot; VSD: Ventricular septal defect; TAPVR: Total anomalous pulmonary venous return

In the entire cohort (65 patients), the mean time to tracheostomy from cardiac surgery was 30±16 days. The median time for ICU stay after tracheostomy was 38 (21–108) days, while the mean time for ICU stay was 104±87 days. Furthermore, the mean time for hospital stay was 126±97 days. In-hospital mortality was noted in 20 of the patients (30.8%) who underwent tracheostomy. The mortality rate was 28.6% (12/42) in the biventricular heart subgroup and 34.7% (8/23) in the univentricular heart subgroup (Table 2). According to the surgery type, mortality rate was found in 7 out of 34 (20.5%) in the total correction subgroup and 13 out of 31 (41%) in the palliative surgery subgroup. The outcomes are presented in Table 3.

Five patients (7%) transferred to another institution under pediatric ICU for further noncardiopulmonary disease treatment. Three of these patients were decannulated and discharged after treatment completion with good recovery; however, two of them died during the follow-up at the last transferred center. Forty patients (62%) were discharged from our center and 26 (40%) were decannulated, discharged, and recovered, while 4 out of 26 died because of unknown reasons during follow-up. Twenty-two of these patients survived without any tracheostomy-related disability. A total of 14 patients (22%) were discharged with a tracheostomy cannula and home-type mechanical ventilator (HMV). In patients who could be discharged with an HMV; the mean follow-up time with

Table 3. Outcomes

Variables (%, mean±SD, median (range)	All patients (n=65)	
	n	%
Time to tracheostomy (day)	30±16	
PCICU stay with tracheostomy (day)	38 (21–108)	
Total PCICU stay (day)	104±87	
Total hospital stay (day)	126±97	
Follow-up duration with HMV (day)	254±101	
In hospital mortality	20	30.8
In hospital mortality (palliative operations)	13	41.9
In hospital mortality (total corrections)	7	20.5

SD: Standard deviation; PCICU: Pediatric cardiac intensive care unit; HMV: Home type mechanical ventilator

HMV was 254±101 days. Five of them (36%) were decannulated, and five of them (36%) survived with the help of HMV. Three of them (21%) died while on HMV and one of them was lost to follow-up (Fig. 1).

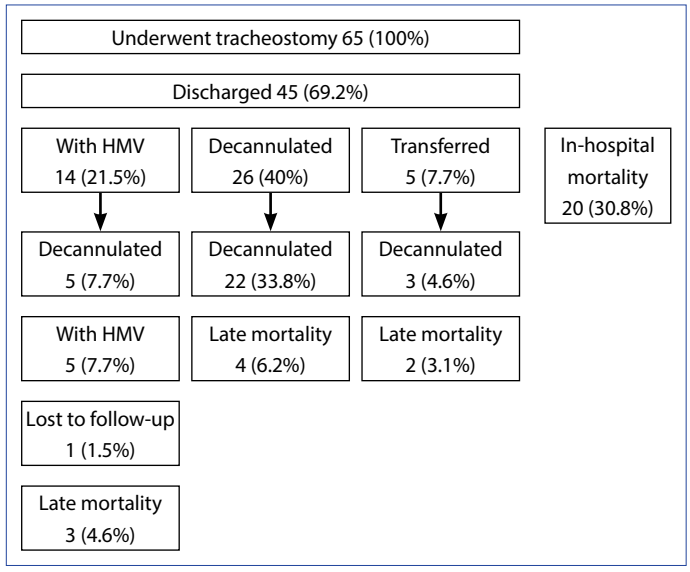

Figure 1. Follow-up chart of the patients.
HMV: Home-type mechanical ventilator.

Discussion

This study retrospectively reviewed the results of CHD and tracheostomy patients in the last 5 years at our hospital. A total of 2814 patients underwent surgery for CHD and 65 of these patients required tracheostomy throughout the course (2.3%). Published reports of patients requiring tracheostomy ranged from 0.2% to 2.7%.[5]

It is an established fact that pediatric cardiac patients who require a tracheostomy during the treatment course are at risk of a significantly higher mortality and morbidity rates compared to the normal population and other CHD patients who were treated without the need for tracheostomy. In the literature, the hospital survival following CHD surgery and tracheostomy is reported at approximately 60.5% to 80%[1,4,6,7] which is close to our series, where 40 out of 65 (62%) survived until discharge. Although pediatric patients with tracheostomy and CHD have a higher risk of mortality than other patients, precise comparisons remain unclear.[5]

Almost 20 years ago, an earlier report from our center retrospectively reviewed patients between 2002 and 2005, with a similar cohort entitled "Indications and results of tracheostomy in pediatric postoperative intensive care unit."[8] The patient population was similar; however, patients in our series are more complicated both for anatomical classification of the defects and surgical techniques that were used for repair. Additionally, experience and technological advancements already evolved that allowed optimal management of many sick children that had poor recovery in the earlier series, such as the use of ECMO that became routine practice after 2015.

Also, we had the opportunity to evaluate and compare two different time zones to assess how our clinic has evolved since then. In our series, the time on ventilator from the heart surgery to tracheostomy is longer (25.1±11 days vs. 30±16 days), the mean time for ICU stay was 55.8±17.3 days vs. 104±87 days, and the mean hospitalization time was 71.6±34.6 days vs. 126±97 days, respectively. The total mortality is 48% vs. 30.8%. In the days from the operation to tracheostomy, the length of ICU stay and the length of hospitalization were longer for our recent series, and the mortality rates remained better than before. Moreover, advancements in medicine were demonstrated in the cohort containing complex patients with hemodynamic instability, high inotrope scores, and a significant need for ECMO application, and technology allowed the pediatric cardiac team to be more equipped in pushing for survival in these patients. Technological advancements in the field of non-invasive ventilation treatment have also allowed the ICU team to afford more aggressive therapy for mechanical ventilator-dependent patients with CHD; thus, tracheostomy as an option is maintained as the last resort, if clinically warranted.

The distribution of the tracheostomy patients according to the univentricular versus biventricular pathways was also analyzed. There were 42 out of 65 patients in the biventricular group and 23 out of 65 in the univentricular group. In the biventricular patients, 34 patients underwent corrective procedures, where the mortality was 7 out of 34 and eight of them had palliative procedures and a mortality of 5 out of 8, with a total mortality of 12 out of 42. In the uni-

ventricular group, where the patients were managed with palliative surgical strategies, the mortality was 8 out of 23. When the cohort is stratified between corrective and palliative procedures, the mortality tends to be better for patients going through corrective procedures, with 7 out of 34 versus 13 out of 31. The reduced survival in single-ventricle patients may be attributed to the complex cardiopulmonary interactions, underlying pulmonary disease, and the requirement for low pulmonary vascular resistance to maintain a single-ventricle physiology.[5] Furthermore, the corrective pathway provides better hemodynamics, creating less complications through less residual defects.[6]

Tracheostomy is an essential procedure which facilitates patient care, ambulation, oral feeding, rehabilitation, and ventilator weaning and has been increasingly performed in children requiring prolonged mechanical ventilation; however, in children, a consensus is lacking regarding the indications and right timing.[9–11] In some patients with a tracheostomy, they could be discharged home with the HMV. In our series, 26 out of 65 patients (40%) were decannulated and discharged home with good recovery, and 14 patients (22%) were discharged with a tracheostomy cannula and HMV. Advantages of HMV include decreased hospital-acquired infections, increased mobility, improved nutrition, and decreased healthcare costs.[12] However, the safety profile of HMV especially out of the hospital is still questioned by both doctors and parents.

The study limitations include its retrospective design and the limited number of patients. As is typical for single-center studies, these results may not be applicable to all centers performing pediatric cardiac surgery.

Conclusion

Tracheostomy for children with CHD after pediatric heart surgery is rare and is associated with high risks; however, sometimes, it can be a life saver for patients that require prolonged mechanical ventilation and provides the patient, physician, and family an opportunity to decrease the hospitalization period, thus preventing infections, improving nutrition, increasing mobility, and lowering hospital costs.

Disclosures

Ethics Committee Approval: The study was approved by The Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital Ethics Committee (Date: 29/11/2022, No: E-28001928-604.01.01).

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RESEARCH ARTICLE

Comparing Two Models of Pediatric Cardiac Care Establishment in a Developing Country

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ABSTRACT

Objectives: Multidisciplinary cardiac care is well known to lead to improved outcomes. In this study, two different organizational models (surgeon-led and team-based units) for pediatric cardiac intensive care unit (ICU) located in a developing country setting and their early postoperative outcomes for patients with pediatric congenital heart disease were compared.

Methods: A total of 246 infants and children who underwent surgery for congenital cardiac diseases were retrospectively analyzed. The correlations between the perioperative patient data of both models were analyzed and compared. The predictive factors for morbidity were calculated.

Results: No significant difference was observed in the Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality category and estimated mortality rate between groups. However, a statistically significant difference was observed in the STS-EACTS estimated postoperative length of stay and estimated major complication rate between groups. The extubation time and length of ICU stay varied significantly between groups.

Conclusion: Compared with the surgeon-led model, the team-based model resulted in superior postoperative patient outcomes in terms of morbidity, shorter extubation time, and ICU length of stay. Thus, in developing countries, higher morbidity rather than mortality may be anticipated when undertaking congenital heart surgery in non-neonatal age groups without a multidisciplinary team to support the surgeon. Therefore, higher major complications can be expected when congenital heart surgery programs have to be established despite the lack of experienced staffing.

Keywords: Cardiac intensive care, cardiac surgery, congenital heart diseases

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Introduction

With the rapidly growing specialty of pediatric cardiac intensive care, the demands of children with congenital heart disease (CHD) are being met.[1,2] Intensive care unit (ICU) workflow with multidisciplinary teams is well known to result in better outcomes.[2,3] At present, the collaboration between surgery and cardiac critical care has resulted in drastically improved results, with ICU mortality estimated in single-digit percentages.[4] For the perioperative management of these critically ill children, organized pediatric cardiac ICUs have become essential because of the growing difficulty of congenital heart repairs in the modern era and the special needs for managing children following cardiac surgery.[1] Furthermore, with the wider availability of accurate diagnostics and the improving potential for total anatomic repair, an increasing number of children are undergoing cardiac surgery for congenital heart disorders.[2] Consequently, there is a growing need for specialists to provide dedicated and high-quality intensive care to these critical patient groups.

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Attention has always been concentrated around the organizational structure and staffing of cardiac ICUs.[1] Previous studies have reported the positive impacts of intensive care with a cardiac team on clinical outcomes; nevertheless, data regarding this topic are limited.[1,5] Despite progress in the management of CHDs, there continue to be major discrepancies worldwide in the standard and availability of pediatric cardiac care.[6]

In many developed countries, pediatric cardiac intensive care has transformed into a separate field with specialized programs in practice.[2] On the other hand, in developing nations, pediatric cardiac surgery is an ongoing challenge, and current cardiac intensive care models cannot be implemented because of severe resource constraints that must be overcome. It is challenging to put into practice advanced methods to address the surgical needs of a substantial percentage of children with congenital heart defects while dealing with severe financial constraints and maintaining quality with the context of constant job turnover of equipped medical, nursing, and other paramedical personnel.[7] Thus, in these countries, resource limitations in terms of infrastructure, people, and materials require for numerous adjustments in intensive care programs.[5,6] Moreover, these developing countries are still in the early stages of developing pediatric cardiac critical care programs.[5] Pediatric cardiac critical care has not yet established itself as a unique field in developing nations with limited resources.[2]

In this study, we compared the experiences of one surgeon in two different organizational pediatric cardiac care models (i.e., a surgeon-led unit as opposed to a team-based multidisciplinary ICU). Our aim was to compare the early postoperative outcomes of children undergoing congenital heart surgery in a developing country and review the outcomes of both models.

Methods

A total of 246 infants and children who underwent operation for CHDs between June 2017–November 2019 and April 2021–November 2022 were retrospectively included and assigned to group 1 and 2, respectively. Group 1 comprised 123 patients operated in a regional non-referral hospital with a pediatric ICU led by the primary pediatric cardiac surgeon. Group 2 included 123 patients operated in a university hospital with a pediatric cardiac ICU led by a multidisciplinary cardiac team. Neonates were excluded from the cohort to preserve the homogeneity of the study since the number of neonates differed in both groups (55 neonates in group 1 and 7 neonates in group 2).

All patients were operated on by the same surgeon. Their preoperative, operative, and postoperative data up until discharge were evaluated. The Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality and morbidity scoring systems were used to evaluate patients.[8,9] The perioperative data and length of intensive care and hospital stay were reviewed. Besides the difference of staffing, the two centers were equivalent with regard to the availability of resources such as surgical equipment and medications.

In group 1, the pediatric cardiac ICU was managed by one cardiac surgeon, three practitioners, and nursing staff. The patients were admitted to a specialized ICU that was only for patients undergoing pediatric cardiac surgery. Postoperative care of patients was provided by the lead cardiac surgeon on call 24 h a day supported by an anesthesiologist and on-call cardiologists. Clinical decision-making was done on an individual basis by the surgeon.

In group 2, the multidisciplinary patient care team consisted of two pediatric intensive care specialists, two cardiac anesthesiologists, two pediatric cardiac surgeons, two pediatric cardiologists, nursing staff, and a respiratory physiotherapist. The patients were admitted to a pediatric ICU. The treatment plan was carried out under the supervision of the intensive care specialist, with mainly the support of pediatric cardiac surgery and cardiology.

Patient outcomes and perioperative data were retrospectively analyzed for the two time periods. The length of hospital and ICU stay, length of mechanical ventilation, mortality, and postoperative complications were analyzed. As defined by STS-EACTS, the following conditions were accepted as postoperative complications: acute postoperative renal insufficiency necessitating either temporary or permanent dialysis, postoperative atrioventricular block requiring a permanent pacemaker, postoperative neurologic impairment that persisted after discharge, need for mechanical circulatory support postoperatively, diaphragm paralysis/phrenic nerve damage, and unanticipated reoperation.[9]

Statistical Analysis

Statistical analyses were conducted using the MedCalc Statistical Software, version 12.7.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2013). The Shapiro–Wilk test was used to investigate the normality of continuous variables. For non-normally distributed variables, descriptive statistics were presented as median and interquartile range (1–3) values. Values with skewed distribution were analyzed using non-parametric statistical techniques. The Mann–Whitney U test was used to compare two groups with non-normal distributions. Pearson chi-square and Yate's continuity correction tests were used for comparison of categorical data. Logistic regression analysis was used for multivariate evaluation of perioperative factors affecting morbidity. A two-sided p-value less than 0.05 was considered statistically significant.

Table 1. Table of perioperative patient data and the univariate analysis

	Total (246pt)		Group 1e (123pt)		Group 2 (123pt)		p
	n	%	n	%	n	%	
Age (month)	14.3 (46.2–5)		10 (23–5)		28.2 (59.5–6.4)		<0.001
Age groups							
1–12 months	115	46.7	70[a]	56.9	45[b]	36.6	<0.001
12–36 months	57	23.2	33[a]	26.8	24[a]	19.5	
36–72 months	41	16.7	7[a]	5.7	34[b]	27.6	
72 months	33	13.4	13[a]	10.6	20[a]	16.3	
Sex							
Female	113	45.9	58[a]	47.2	55[a]	44.7	0.701
Male	133	54.1	65[a]	52.8	68[a]	55.3	
Weight	8 (13.7–5)		6.2 (9.5–4.8)		11 (16–6)		<0.001
Height	72 (96–58)		65 (78–56)		90 (108–65)		<0.001
Body surface area	0.39 (0.6–0.28)		0.33 (0.44–0.27)		0.52 (0.69–0.32)		<0.001
Cyanosis	118	48	49[a]	39.8	69[b]	56.1	0.011
Pulmonary hypertension	136	55.3	82[a]	66.7	54[b]	43.9	<0.001
Re-operation	70	28.5	11[a]	8.9	59[b]	48	<0.001
STS-EACTS-mortality category							0.864
Category 1	41	16.7	22[a]	17.9	19[a]	15.4	
Category 2	122	49.6	61[a]	49.6	61[a]	49.6	
Category 3	32	13	14[a]	11.4	18[a]	14.6	
Category 4	51	20.7	26[a]	21.1	25[a]	20.3	
STS-EACTS estimated mortality rate	3 (4.9–1.9)		2.6 (4.6–1.9)		3 (6.7–2.4)		0.164
STS-EACTS Estimated post-operative length of stay	11.7 (14.9–7.7)		8.3 (13.8–7.7)		12 (14.9–9.4)		0.001
STS-EACTS Estimated major complication rate	6.9 (12–3.4)		4.3 (9.9–3.4)		7.2 (12–6.3)		<0.001
Cross time	93 (135.2–57.7)		94 (135–64)		89 (136–50.5)		0.22
Bypass time	138 (190.5–98.2)		140 (198.5–100.7)		131 (183.2–89.5)		0388
Ultra-Fast-Track Extubation	83	33.7	14[a]	11.4	69[b]	56.1	<0.001
Complication rate	36	14.6	28[a]	22.8	8[b]	6.5	<0.001
Renal insufficiency	12	33.3	9	25	3	8.3	
AV block	5	13.8	3	8.3	2	5.5	
Neurologic impairment	1	2.7	1	2.7	0	0	
ECMO	17	47.2	14	38.8	3	8.3	
Diaphragm paralysis	1	2.7	1	2.7	0	0	
Mortality rate	15	6.1	10[a]	8.1	5[a]	4.1	0.287
ICU stay	2 (7–1)		5 (12–2)		1 (2–1)		<0.001
Hospital stay	12 (20–7)		14 (22–8)		10 (16–7)		0.007

[a,b]: Each superscript letter denotes a subset of groups whose column proportions do not differ significantly from each other at the 0.05 level. STS-EACTS: Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery; AV: Atrioventricular; ECMO: Extracorporeal membrane oxygenation; ICU: Intensive care unit

Results

Data relevant to procedures and perioperative patient information are summarized in Tables 1 and 2. Group 1 included patients who were managed postoperatively in a pediatric ICU led by a cardiac surgeon without a specialized intensivist. Group 2 comprised patients admitted to a specialized team-based pediatric cardiac ICU. A statistically significant difference was observed between the age of patients in both groups (p<0.001) (Table 1). On the other hand, the two patient groups were equally dispersed in terms of sex. The weight, height, and body surface areas between the two groups varied significantly (all p<0.001). Additionally, no difference was observed in terms of the cyanotic nature of the pathology between the two groups. With regard to the presence of pulmonary hypertension and reoperation status of patients, a significant variation was observed (all p<0.001).

Based on the STS-EACTS mortality scoring system, no significant difference was observed in the mortality catego-

Table 2. Table of the logistic regression analysis

Variables	Significance	Exp(B)	95% CI for Exp(B)
Body surface area	0.710	0.286	(0.000–209.003)
Age	0.843	0.996	(0.953–1.040)
Cyanosis	0.036	5.498	(1.119–27.009)
Redo	0.119	4.060	(0.697–23.642)
Pulmonary hypertension	0.451	1.871	(0.367–9.525)
STS-EACTS mortality category	0.470	0.637	(0.187–2.165)
STS-EACTS estimated mortality rate	0.756	1.062	(0.726–1.554)
STS-EACTS estimated post operative length of stay	0.120	0.782	(0.573–1.066)
STS-EACTS estimated major complication	0.301	1.138	(0.890–1.456)
Cross time	0.025	0.979	(0.960–0.997)
Bypass time	<0.001	1.033	(1.016–1.050)
ICU length of stay	0.109	1.053	(0.988–1.122)
Hospital length of stay	0.412	0.980	(0.935–1.028)
Surgeon-led ICU model	0.016	0.151	(0.032–0.706)

Exp(B): Odds ratio; CI: Confidence interval; STS-EACTS: Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery; CU: Intensive care unit

ry and estimated mortality rate between the two groups. On the other hand, the STS-EACTS estimated postoperative length of stay and estimated major complication rate were statistically significant between groups (p=0.001 and p<0.001, respectively).

Regarding operative data, no statistically significant difference was observed in the cross-clamp and bypass times between the two groups. Nonetheless, the ultra-fast-track extubation success differed significantly between them (p<0.001). Furthermore, a significant difference was observed with regard to the occurrence of postoperative complications between the two groups (p<0.001). Notably, no significant difference was found between the mortality rates of both groups. However, there was a significant difference between the ICU and hospital length of stay of both groups (p<0.001 and p=0.007, respectively).

Based on the results of logistic regression analysis, the cyanotic nature of the pathology, cross-clamp duration, bypass duration, and cardiac intensive care strategy were statistically significant predictors of morbidity (p=0.036, p=0.025, p<0.001, and p=0.016, respectively).

Discussion

The intensive care period forms a crucial component of the care of patients undergoing surgery for CHDs. Globally, three main postoperative cardiac ICU systems are used, with either surgeons, intensivists, or cardiologists providing the initiative regarding the plan of action in ICUs. In the early years of congenital heart surgery, pediatric cardiac surgeons were mainly responsible for the postoperative intensive care of patients.[2,5] However, in the past decades, further specialties, especially pediatric cardiac intensivists, have begun to play a bigger role in this field.[5] On the other hand, these practices differ widely between developing and developed countries.[7] Additionally, regional and institutional factors influence the strategy employed; thus, the standard of care among regions of a single country vary and are nonuniform. In developed countries, units with a multidisciplinary cardiac care team are widely established. Compared with high-income nations, pediatric cardiac intensive care centers are not generally available in low- and middle-income countries. In addition, resource constraints deem cardiac intensivists a luxury and make the surgeon responsible for postoperative care in ICUs.[7] This shortage is because of the lack of infrastructure, financial resources, and personnel resources required for a specialized pediatric cardiac intensive care program.[2,7,10] Our country, Türkiye, is still developing, yet hospitals vary according to the standard of care which they offer from developing to developed country levels. Hence, different strategies of pediatric cardiac intensive care are being implemented in different hospitals across the country. Notably, the main resource constraint in our country is the lack of experienced staffing and organizational outline for the establishment and management of pediatric cardiac programs in peripheral centers with frequent staff turnover that stand in the way of sustainable and efficient teamwork. In surgical programs of centralized hospitals for pediatric cardiac care, the strategies being applied are continually evolving. Moreover, in the case of pediatric cardiac surgery, there is a compulsory service system for all doctors where, to this day, they are

assigned to a hospital in an unprogrammed manner. These hospitals have highly differing availability of resources and organizational model practices for pediatric cardiac care. This variation has been demonstrated in our study by the differing experiences with mortality and morbidity of one cardiac surgeon in two regions of the same country.

Mortality following cardiac surgery has been routinely used as a quantifiable indicator to assess the quality of pediatric cardiac surgical treatment. Surgical complexity, severity of CHD, and preexisting comorbidities all have a major impact on postoperative mortality.[10] In previous studies, the mortality rate of children following heart surgery was high in low- and middle-income countries, in contrast to the reported mortality rate of <5% in high-income countries when compared according to their pediatric cardiac care strategy.[10] In our study, the overall mortality in group 1 was two-fold higher than that in group 2. Nonetheless, it was statistically insignificant in infants and children. Moreover, the recorded mortality rate in group 1 was approximately three times the estimated mortality rate, which suggests a possible benefit of multidisciplinary teams in cardiac care.

Cyanotic CHD and longer cardiopulmonary bypass duration have been previously reported to be predictive variables for developing major complications postoperatively.[11] Our results were in agreement with this study. However, cross-clamp duration and staffing pattern were shown to be predictors of morbidity as well. Notably, our cohort included operations of higher surgical complexity with longer cross-clamp duration compared with those in the previous study, which might explain the association between cross-clamp duration and higher morbidity. In literature, prolonged cardiopulmonary bypass and aortic cross-clamp duration are significantly correlated with postoperative morbidity. Thus, to avoid morbidity, close monitoring for postoperative complications or transferring to centers with multidisciplinary teams might be considered for patients who are predicted to have prolonged cross-clamp and bypass durations in developing countries with staff constraints. On the other hand, the results of our multivariate analysis indicate that the intensive care strategy used and staffing have a more significant effect on patient morbidity compared with perioperative factors such as the cyanotic nature of the pathology and bypass duration. Thus, it may be deduced that a multidisciplinary-team-based approach for cardiac care effectively reduces postoperative complications.

Among the STS-EACTS postoperative complications, low cardiac output and arrythmia are the most common.[12] In our cohort, low cardiac output requiring extracorporeal membrane oxygenation support was the most common complication followed by the need for dialysis and arrythmias, which were more commonly seen in group 1. The possible explanation for this finding may be the younger age of patients in this group since morbidity is expected to increase as age decreases.[13] Moreover, in our practice in group 1, dialysis was used to support the overall hemodynamic status of the patient when needed, in addition to its application in kidney injury. The clinical interpretation of patients differs between surgeons and intensivists. In addition, the approach to hemodynamic instability varies, and an intensivist might approach with a different treatment plan. Furthermore, intensivists are specialists with additional training and experienced in non-cardiac organ failure and related treatments in addition to their experience with congenital and acquired heart diseases.[3] A previous study reported that the reduction in postoperative morbidity and mortality following congenital heart surgery in recent decades can be partially credited to the creation and advancement of pediatric cardiac intensive care specialists.[14] This difference in clinical judgement and choice of management plan of intensivists is one of the possible explanations for the difference in morbidity between the groups. In addition, this expertise might allow for an earlier recognition and treatment of postoperative complications, which may further explain the difference in morbidity recorded in this study.

Furthermore, the additional pressure on the surgeon caused by the lack of staffing and added responsibility of intensive care might be another factor contributing to the higher postoperative morbidity in group 1. Thus, it can be argued that when the surgeon has to claim responsibility of the ICU, the capacity for patient management in the ICU is lowered, and higher rates of complications and mortality from postoperative complications may be seen. Multidisciplinary units benefit not only the patients but also the surgeons.[15] In addition to performing the operation, being responsible for the entirety of postoperative care and being the on-call caretaker for 24 h make it exceedingly stressful for the surgeon.[7] Considering these factors, the advantages of a team-based cardiac care strategy for the surgeon include a simplification of everyday tasks, ease of capacity management, and the ability to share the load of postoperative care with colleagues.[15] As a result, creating a strong team with delegated tasks leads to superior outcomes.[2,7] The improvements in mortality and morbidity recorded in this study exemplify the advantages of team-based cardiac ICUs and specialized intensivists.

An ICU model incorporating intensivists has been previously shown to reduce the length of hospital stay.[1] In addition, previous studies have reported an association between reduced length of ICU stay and specialized pediatric

cardiac ICU.[1,10,16,17] The results of our analysis indicate that a cardiac-team-led ICU have a statistically significant impact on ICU and hospital length of stay. This outcome may be caused by the increased occurrence of postoperative complications in the surgeon-led ICU, which may have resulted in prolonged length of hospital and ICU stay. The results of this study indicate that the presence of a multidisciplinary team significantly impacts the outcomes of congenital heart surgery. Thus, when undertaking cardiac surgery in developing countries with resource limitations, efforts should be made to support surgeons with a multidisciplinary team to share the ICU's responsibilities in order to improve patient outcome by reducing morbidity and cost burden on healthcare systems.

The main limitations of this study rooted from its retrospective nature. Data could not be collected prospectively because of the institutional differences between the two hospitals and the same lack of resources and staffing mentioned previously. The dataset includes a small number of patients that might not be sufficient to reach a clear consensus. Furthermore, the scoring system used in this study may not always accurately reflect the true surgical complexity of the cases. In addition, separating the impacts of surgical pitfalls from the impact of ICU care on patient outcomes is impractical and cannot be performed. When evaluating different strategies of pediatric cardiac critical care setting, the ideal independent outcome to measure would be a factor that represents the skill and quality of care delivered by the intensive care staff and is unaffected by treatment provided in advance to ICU admission. However, accurate parameters needed for such an evaluation have not yet been created. Thus, the patient outcomes in the two different ICU models cannot be attributed solely to the ICU setup, and outside factors have to be considered. Nevertheless, this particular limitation was minimized in this study by keeping the surgeon and surgical approach constant in both models. Therefore, the outcomes were made more comparable.

Conclusion

The introduction of a multidisciplinary pediatric cardiac intensive care model as opposed to a surgeon-led cardiac ICU model resulted in improved postoperative patient outcomes in terms of morbidity and shorter extubation time and ICU and hospital stay. Notably, higher morbidity rather than mortality may be expected while carrying out pediatric heart surgery on children in countries with human resource constraints. Lastly, more efforts should be made to achieve this team-based model for the postoperative care of this delicate patient group, especially in developing countries.

Disclosures

Ethics Committee Approval: The study was approved by The Koç University Committee on Human Research Ethics Committee (Date: 24/07/2023, No: 2023.244.IRB1.078).

Informed Consent: Written informed consent was obtained from all patients.

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CASE REPORT

Hypoxic Spell After Abdominal Surgery in Tetralogy of Fallot Patient: From Being Asymptomatic to Symptomatic

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ABSTRACT

Tetralogy of Fallot is a cyanotic congenital heart disease involving hypoxic episodes. We herein present a case of a patient who underwent the Duhamel operation for Hirschsprung's disease. The patient had hypoxic seizure triggered by surgical stimulation, anesthesia effect, and postoperative agitation and was diagnosed with Tetralogy of Fallot via echocardiography postoperatively.

Keywords: Anesthesia, child, congenital heart diseases, noncardiac surgery, tetralogy of fallot

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Introduction

Hirschsprung's disease refers to the formation of an aganglionic segment in the distal bowel during intestinal development. The surgical treatment option for this disease is the Duhamel operation. Cyanotic heart disease is mainly caused by Tetralogy of Fallot (TOF).[1] TOF has four components: ventricular septal defect (VSD), right ventricular outflow obstruction, overriding of the aortic root over the ventricular septum, and right ventricular hypertrophy. We herein present a case of a patient who was asymptomatic in the preoperative period but was diagnosed with TOF and had hypoxia postoperatively.

Case Report

A 9-month-old boy weighing 9.5 kg was evaluated for a planned Duhamel operation. The patient had no known comorbidities, medication use, dyspnea, hypoxia, cyanosis, spell attack, or diagnosis of TOF. Preoperative echocardiography (ECHO), which was requested for secure anesthesia management, revealed subaortic and wide VSD, 2–2.5-mm-thin patent ductus arteriosus (PDA), significant valvular–supravalvular pulmonary stenosis, and 50% overriding of the aorta on the interventricular septum. Pediatric cardiology consultation suggested preoperative infective endocarditis prophylaxis. In the intraoperative preinduction monitoring, oxygen saturation was found to be 94%; systemic blood pressure, 95/55 mmHg; and pulse rate, 120/min. Mask induction was performed using 8% sevoflurane, followed by intravenous administration of 0.5 µg/kg fentanyl and 0.6-mg/kg rocuronium bromide. The patient was intubated with a 3.5 mm cuffed endotracheal tube. Administration of sevoflurane (1.5%–2%) and remifentanil as analgesic (0.0125–0.1 mcg/kg/min) was initiated for the maintenance of anesthesia. When the mean arterial pressure decreased due to surgical bleeding, intermittent ketamine analgesia was preferred over remifentanil. During the operation, which lasted 4.5 h, fluid balance and maximum allowable bleeding amount were calculated and compensated for. No hypotensive episode occurred. Postoperatively, the patient created a spontaneous sufficient tidal volume and was extubated, and the oxygen saturation was 94%–96%. He was conscious and had spontaneous eye opening, and his motor movement had reached a sufficient power. The patient's spontaneous breathing continued, and when he started crying, saturation began decreasing. Oxygen support was provided, and despite providing positive pressure support, saturation dropped to 45%. The patient's hemodynamics

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was stable, and all possibilities were simultaneously evaluated to determine the differential diagnosis of hypoxia in an asymptomatic patient with a medical history. No lung sound abnormalities, congestion, bronchospasm, or laryngospasm was noted. To rule out pain-related shallow breathing, fentanyl was administered. It was observed that saturation increased when the patient calmed down but dropped again when he started crying. Cardiology consultation was requested in the operating room. ECHO revealed an ejection fraction of 70, VSD of 12.5 mm in the subaortic region with a bidirectional shunt, stenosis due to the muscle band 10-mm below the pulmonary annulus, and 2–2.5-mm-thin PDA; the ECHO report was interpreted as pink TOF. With the recommendation of the cardiology consultant, 20-mL/kg bolus fluid replacement and 1-mg/kg sodium bicarbonate were administered to the patient. Initiation of postoperative propranolol was suggested. The patient was reintubated and transferred to the intensive care unit. After being sedated and receiving propranolol in the intensive care unit, the patient was extubated on postoperative day 4. After consultation with the cardiovascular surgeon, following angiography, elective TOF correction surgery was scheduled.

Discussion

The present case demonstrates how an asymptomatic TOF patient can become symptomatic after major surgery and anesthesia-related hemodynamic changes.

TOF is characterized by hypercyanotic episodes (hypoxic spells). Some studies have reported cases that were not diagnosed with TOF until adulthood despite prenatal screening.[1] Anesthesia management of these patients is challenging and requires understanding of the pathophysiology of the disease. To reduce agitation, premedication is preferable. However, it can trigger hypoxic spells in patients with TOF due to secondary hypoxia, hypercarbia, and increased pulmonary vascular resistance (PVR). In patients with shunt lesions, care should be taken to ensure there are no air bubbles in intravenous fluid therapy as they can enter the arterial system and cause paradoxical air embolism.[2] Since pulmonary perfusion is low in patients with right-to-left shunts, inhalation induction is slow and intravenous induction is rapid.[3] In these patients, neuroaxial blocks should be avoided to prevent a decrease in systemic vascular resistance (SVR). Furthermore, in this patient population, the goal is to reduce PVR and increase pulmonary artery blood flow and lung perfusion to prevent hypoxia. Because a decrease in SVR or an increase in PVR in bidirectional shunts will increase the right-to-left shunt transition, hypoxia may occur. In the present case, the hypoxic spell may have been caused by exposure to an anesthetic agent that decreases SVR and increases endothoracic pressure with mechanical ventilation, which decreased venous return to the right ventricle. Surgical factors such as prolonged surgical duration, bleeding, and decreases in mean arterial pressure and intravenous volume can also play a role. Agitation, crying, and stress after extubation can make an asymptomatic TOF patient visibly cyanotic. To reduce the PVR/SVR ratio during surgical procedures in patients with TOF, the occurrence of hypercarbia, acidosis, and hypoxia should be avoided.[4] In addition, hypotension should be prevented, and anesthetic agents to be used should be carefully selected. Ketamine is often preferred owing to its ability to increase SVR. The effects of anesthetic agents on PVR and SVR are presented in Table 1.

Table 1. Effect of anesthetic agents on PVR and SVR[5]

Anesthetic drug	SVR	PVR	Dose
Potent volatile agent	↓	↓	0.5–1 MAC
Nitrous oxide	–	↑	
Opioids			
Fentanyl	↓		1–2 mcg/kg
			0.5–2 mcg/kg/hr
Morphine	↓		0.05–0.2 mg/kg
			0.02–0.2 mg/kg/hr
Midazolam	–	–	0.1 mg/kg (IV)
Ketamine	↑	–	1–2 mg/kg (IV)
			5–20 mcg/kg/min
Propofol	↓	–	2–3 mg/kg
			100–300 mcg/kg/min
Dexmedetomidine	↑–↓	↓	0.2–1 mcg/kg/hr

↑: Increase; ↓: Decrease; PVR: Pulmonary vascular resistance; SVR: Systemic vascular resistance; MAC: Minimum alveolar concentration; IV: Intravenous

Intravenous fluid bolus should be administered to improve right ventricular filling and pulmonary flow. Furthermore, beta-blockers should be used to help reduce infundibular spasm, improve right ventricular outflow obstruction, and increase pulmonary flow. Conversely, phenylephrine should be administered to increase systemic afterload, with the patients placed in the knee–elbow position. Mild compression of the intraoperative abdominal aorta has the same effect as the knee–elbow position. To prevent postoperative agitation, morphine can be used.[1] In the present case, intravenous volume was provided through fluid bolus and erythrocyte suspension replacement. Ketamine was used to increase SVR, fentanyl to prevent agitation under operating room conditions, and sodium bicarbonate to address acidosis. Subsequently, sedation was deepened, and the patient was reintubated and transferred to the intensive care unit with mechanical ventilator support for better control of hypercarbia and hypoxia.

Conclusion

In the anesthesia management of patients with TOF, intravenous volume and SVR must be preserved, conditions and medications that increase PVR must be avoided, and hemodynamic stability must be ensured. Ketamine is a good treatment of choice as it increases SVR. Joint assessment by an anesthesiologist, cardiologist, pediatrician, and cardiovascular surgeon is recommended when planning surgical procedures for these patients. Perioperative management of patients with TOF relies on a thorough understanding of the pathophysiology of the disease, planned operation, and effects of the anesthetic drugs used.

Disclosures

Informed Consent: Written informed consent was obtained from patient's family.

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