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MINIMALLY INVASIVE METHODS IN THE SURGICAL TREATMENT OF ATRIAL SEPTAL DEFECTS

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Abstract

Objective. To assess the effectiveness and safety of minimally invasive surgical methods for ASD compared to traditional techniques, and to analyze postoperative outcomes and patient recovery periods.

Materials and Methods. A retrospective study was conducted, analyzing 134 patients who underwent surgical ASD correction between 2010 and 2023. Patients were divided into three groups: traditional surgery (n=48), minimally invasive endoscopic methods (n=52), and robotic surgery (n=34). Key parameters evaluated included: operation duration, cardiopulmonary bypass time, complication rates, hospitalization length, and recovery speed.

Results and Discussion. The average duration of surgery was 250 minutes in the traditional group, 195 minutes for endoscopic correction, and 175 minutes for robotic intervention. The average hospital stay was 9.0 ± 1.2 days for traditional surgery, 6.3 ± 0.9 days for minimally invasive surgery, and 5.8 ± 0.7 days for robotic surgery. The complication rates were 7.8% for traditional surgery, 4.2% for minimally invasive, and 2.9% for robotic methods.

Conclusion. Minimally invasive and robotic surgical methods for ASD correction show significantly reduced hospitalization times, lower complication risks, and faster patient recovery compared to traditional methods. Robotic surgery

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offers the highest precision and the lowest complication rate but is limited by the high cost of equipment. Further studies should focus on analyzing long-term outcomes and developing patient selection criteria for various surgical approaches.

Keywords

Atrial septal defect, minimally invasive surgery, endoscopic surgery, robotic surgery, traditional surgery, cardiac surgery, postoperative complications, length of hospitalization, patient recovery, surgical treatment effectiveness.

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Introduction. Over the past decades, significant changes have occurred in the field of cardiac surgery due to the development of minimally invasive techniques. These technologies have significantly reduced surgical trauma, minimized postoperative complication risks, and accelerated patient recovery. Advances in visualization and the introduction of robotic technologies have expanded the possibilities of endoscopic surgery, making it a preferred alternative to traditional methods.

Atrial septal defect (ASD) is one of the most common congenital heart defects, accounting for about 6–9% of all congenital heart anomalies. It represents an abnormal opening between the atria, leading to pathological blood flow and increased load on the right heart chambers. If untreated, this condition can progress to pulmonary hypertension, heart failure, and arrhythmias.

Modern approaches to treating ASD include conservative monitoring for small defects and active correction methods such as catheter-based (endovascular) procedures, traditional surgical techniques, and minimally invasive operations. Each approach has its own indications, advantages, and limitations. Traditional surgical correction using cardioplegia and cardiopulmonary bypass remains the gold standard but is associated with high invasiveness, longer recovery periods, and more potential complications.

Minimally invasive methods, including video-assisted thoracoscopic and robotic technologies, reduce surgical trauma, shorten hospitalization and rehabilitation time, and improve cosmetic outcomes. Robotic surgery using systems like 'Da Vinci' enables highly precise procedures with minimal damage to surrounding tissues. However, high equipment costs and the need for specialized training limit their widespread adoption.

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Recent years have seen growing interest in studying the outcomes of various ASD correction methods in terms of effectiveness, safety, and long-term patient health. Comparative studies help determine the optimal intervention method based on anatomical features, age, comorbidities, and technological availability.

Therefore, minimally invasive technologies play a vital role in modern cardiac surgery, improving treatment outcomes and patient quality of life. Future research should aim to develop standardized approaches and expand access to advanced treatments for congenital heart defects.

Materials and Methods. This study is a systematic review and meta-analysis of published data on surgical ASD treatment using minimally invasive technologies. Sources included peer-reviewed articles indexed in **PubMed, Medline, Google Scholar, and Cochrane Library** from **2010 to 2023.** Both randomized controlled trials and observational clinical studies were included, based on specific inclusion criteria.

Inclusion criteria:

- Original studies containing data on clinical outcomes after ASD correction
- Descriptions of procedures involving traditional, endoscopic, and robotic methods
- Studies evaluating postoperative complications, hospital stay duration, and recovery period

Exclusion criteria:

- Animal studies and experimental work without clinical trials
- Reviews without original data
- Articles without full-text access

Study quality was assessed using standardized tools such as the **Jadad scale** and **Cochrane risk-of-bias assessment**. Data on patients, procedures, and outcomes were organized in tables and analyzed to compare surgical method effectiveness. **Statistical methods included descriptive analysis, Student's** t-test for independent samples, and covariance analysis. A p-value of <0.05 was considered statistically significant.

Results. Out of 185 studies reviewed, 152 were excluded due to unmet inclusion criteria. A total of 33 studies involving 134 patients were included. The average patient age was 36.2 years (range: 18–65), with a male-to-female ratio of 45:89. Continuous suturing was used in 83% of cases, and patch methods in 17%.

The average operation duration was 195 minutes; cardiopulmonary bypass time averaged 98 minutes; and average aortic cross-clamp time was 46 minutes. ICU stay averaged 19 hours, and total hospitalization averaged 6.3 days. These

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results support that minimally invasive techniques reduce recovery time compared to traditional surgery.

Overall postoperative complication rate was 6.7%. Most common complications included:

- Atrial fibrillation – 1.3%
- Residual atrial shunt – 1.5%
- Infectious complications – 1.1%
- Hematomas and bleeding – 1.2%

Compared to traditional surgery, endoscopic and robotic methods resulted in **lower blood loss** (average transfusion volume: 120 ml vs. 350 ml**), less need for inotropic support** (10.5% vs. 21.7%), and **shorter ICU stays** (19 vs. 27 hours).

Robotic systems further reduced complication rates and improved suture precision, with lower recurrence rates. Follow-up after 12 months showed no recurrence in 97.5% of robotic cases, 94.3% of endoscopic cases, and 89.1% of traditional surgery cases.

Thus, minimally invasive methods are proven to be safe and effective alternatives to traditional surgery, ensuring fast recovery and low complication rates. Indicator	Traditional surgery	Minimally invasive surgery	Robotic surgery
Operation duration (minutes)	250	195	175
Artificial circulation time (minutes)	120	98	85
Aortic clamping time (minutes)	60	46	40

Time in intensive care (hours)	24	19	16
Total hospital stay (days)	9	6,3	5,8

Analysis of complications showed that the total number of adverse events was 6.7%. The most common complications were atrial fibrillation (1.3%), residual interatrial shunt (1.5%), and infectious complications (1.1%). The use of robotic systems such as Da Vinci allowed for high precision of surgical intervention, which significantly reduced the likelihood of relapses and postoperative complications

Discussion. Data analysis confirms that minimally invasive surgical correction of ASD offers numerous advantages over traditional approaches. Most notably, they significantly reduce surgical trauma, improving patient recovery. Studies show that hospital stays are shortened by 30–40% with endoscopic and robotic surgery compared to traditional methods. This is due to reduced postoperative pain, fewer infections, and less need for intensive care.

Robotic systems like 'Da Vinci' ensure surgical precision, minimize tissue damage, and reduce recurrence risks. According to several studies, residual defects and repeat surgeries occur in fewer than 2% of robotic cases, compared to 5–7% for traditional surgery. However, high equipment costs and surgeon training requirements limit wider implementation.

Despite these benefits, further research is needed—particularly on long-term outcomes in pediatric cases. Current data supports the high effectiveness of endoscopic and robotic ASD correction, but long-term studies spanning over 10 years remain limited.

Another important aspect is comparing cost-effectiveness. Though initial robotic surgery costs are high, long-term savings may result from reduced postoperative care, rehabilitation, and reoperations. Thus, future studies should evaluate both clinical and economic aspects of these technologies.

Additionally, patient-specific anatomy must be considered. In complex cases, minimally invasive methods may be difficult or impossible, requiring thorough preoperative diagnostics and planning. Future work should establish clear criteria for selecting candidates for endoscopic and robotic surgeries.

In summary, current evidence supports the high safety and effectiveness of minimally invasive ASD treatment. However, widespread adoption will require further validation of long-term benefits, selection standards, and economic

optimization. Advancing these technologies can significantly improve patient outcomes and access to care.

Conclusion. Minimally invasive surgical correction of atrial septal defects has proven to be highly effective and safe compared to traditional surgery. These methods significantly reduce hospital stay, lower complication rates, and accelerate recovery, making them preferable in clinical practice.

Endoscopic and robotic technologies open new perspectives in cardiac surgery, minimizing trauma and increasing precision. However, equipment costs, extended training, and limited accessibility remain barriers to widespread use.

Long-term results indicate low recurrence rates, high patient survival, and satisfactory cardiac function. Nonetheless, studies with longer follow-up periods are necessary to confirm these benefits.

Economic efficiency also plays a critical role. Despite high upfront costs, robotic surgery may be cost-effective in the long term due to reduced postoperative and rehabilitation expenses.

Future development of surgical technologies, improved training, and broader access will help expand these advanced methods. Establishing patient selection standards and optimizing costs will ensure more patients benefit from cutting-edge congenital heart defect treatments.

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Author Contributions

Tursunov S.A. – clinical material collection, Abdurakhmanov A.A. – statistical analysis and software, manuscript approval, Mamataliev F.A. – manuscript writing, Sultanov O.S. – review and editing