Surgical Complications: Prevention, Treatment, and Strategies to Improve Outcome and Recovery

Lohitha Raja

Dadabayeva Parizodxon Uygunovna

Fergana Medical Institute of Public Health

Abstract

Surgery is a cornerstone of modern medicine, but postoperative complications remain a principal threat to patient safety and recovery. Globally, more than 310 million major surgeries are performed each year, with an estimated 1–4% mortality rate, up to 15% serious postoperative morbidity, and 5–15% readmission within 30 days. Against this backdrop, the last five years have witnessed measurable improvements: in the first quarter of 2024, hospitalized surgical patients were nearly 20% more likely to survive than expected compared to pre-pandemic 2019 baseline data. This article reviews the current evidence on surgical complications — their prevention, treatment, and the strategies most effective in improving outcome and accelerating recovery — with a focused comparison of minimally invasive surgery (MIS) and open surgical approaches using data published from 2020 to 2025.

Keywords: surgical, treatment, prevention, complications, improve, outcome, recovery

Introduction

The burden of surgical complications extends far beyond the operating room. Postoperative adverse events increase mortality, extend hospital length of stay (LOS), compromise patient-reported quality of life, and consume significant healthcare resources. Yet despite decades of safety research, more than one-third of surgical patients continue to experience at least one adverse event, with approximately 60% judged to be potentially preventable. The parallel rise of minimally invasive surgical techniques — encompassing laparoscopic, robotic-assisted, and thoracoscopic approaches — has profoundly reshaped the landscape of surgical recovery, with clinical data accumulating rapidly through 2020–2025 to substantiate their advantages over conventional open surgery across multiple procedure types.[3][4][5][6][7]

This article synthesizes the most current evidence on surgical complication prevention, treatment strategies, and outcome improvement, with particular emphasis on the comparative performance of MIS and open surgery in the contemporary era.

Epidemiology of Surgical Complications (2020–2025)

The global burden of postoperative complications remains substantial. Across 27 countries, approximately 16.8% of elective surgical patients develop one or more in-

hospital complications, with a mortality rate of 2.8% among those who develop complications. More recent population-level data from the United States — drawn from 713 acute care hospitals across 49 states — show that 2019–2024 marked a period of measurable improvement. Post-operative sepsis declined by 9.2%, post-operative respiratory failure by 19.0%, and post-operative hemorrhage by 22.3% over this five-year window. In absolute terms, an estimated 200,000 Americans hospitalized between April 2023 and March 2024 survived episodes of care they would not have survived in 2019.[8][2][9]

Despite system-level gains, procedural variation in complication rates persists. Hernia repair carries a complication rate of approximately 8%, colorectal resections 18–25%, and pancreaticoduodenectomy up to 42%. A 2022 prospective study identified ASA classification, wound contamination class, emergency scheduling, and operative duration as the strongest independent predictors of postoperative morbidity in general surgery patients. Recognition of these risk gradients is foundational to targeted prevention and treatment planning.[10][11][7]

Prevention Strategies

Preoperative Optimization

Effective complication prevention begins before the patient reaches the operating theatre. Modifiable risk factors — including hyperglycemia, anemia, malnutrition, obesity, and active smoking — are amenable to preoperative intervention and have been shown to reduce postoperative morbidity when adequately addressed. The World Health Organization has endorsed 29 specific evidence-based measures for surgical site infection (SSI) prevention, spanning the preoperative, intraoperative, and postoperative phases. Nationally, programs such as the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) — which captures 61% more complications than claims-based systems, including 97% more SSIs — enable hospitals to identify preventable complications and benchmark perioperative performance against peer institutions.[12][13][14][15]

Intraoperative Infection Control

SSIs remain the most common hospital-acquired infection among surgical patients, carrying significant mortality and morbidity risk. A three-step prevention model integrating perioperative antiseptic preparation, multidisciplinary teamwork, and continuous quality improvement (CQI) demonstrates measurable reductions in SSI rates. NICE guidelines recommend antiseptic skin preparation, timed antibiotic prophylaxis within 60 minutes of incision, and structured wound closure protocols to minimize infection risk. The AORN framework further emphasizes strict sterile technique, antibiotic stewardship, and regular auditing of compliance with infection bundles. Post-COVID surveillance data from EPIC Research (2024) illustrate that colorectal surgery SSI rates increased 21% since 2019, underscoring the ongoing need for robust prevention infrastructure even as overall surgical mortality improves.[12][16][17][18][19]

Pain Management and Early Mobilization

Adequate perioperative analgesia is not merely a comfort measure — it is a treatment component that directly influences complication risk. A 2024 prospective cohort study of 1,000 major abdominal surgery patients demonstrated that higher pain scores on postoperative day 1 (POD1) were significantly associated with 30-day total complications (OR = 1.132, 95% CI: 1.076–1.190), infectious complications (OR = 1.126), and non-infectious complications (OR = 1.079). These data argue compellingly for multimodal analgesia — combining epidural blockade, nerve blocks, NSAIDs, and targeted opioid use — as a strategy to improve immune homeostasis, facilitate early ambulation, and reduce recovery time.[20][21]

Treatment of Established Complications

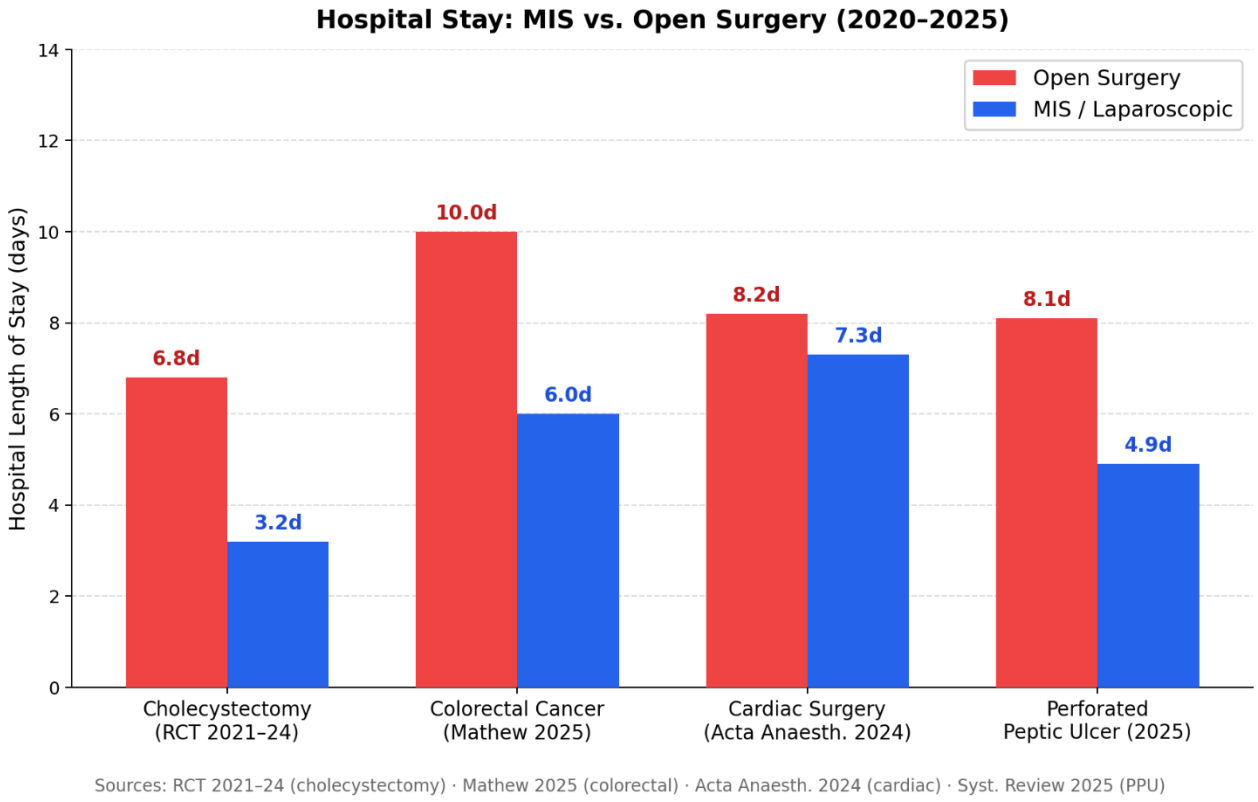
When complications occur, prompt recognition and treatment are the principal determinants of outcome. The concept of "failure to rescue" (FTR) — death following a recognized complication — drives significant inter-hospital variation in surgical mortality and most frequently occurs when multiple sequential complications develop unchecked. Sepsis demands immediate broad-spectrum antimicrobial therapy, fluid resuscitation, and organ support. Anastomotic leaks require source control through percutaneous drainage, endoscopic intervention, or surgical revision depending on severity. Pulmonary complications are managed with chest physiotherapy, incentive spirometry, and bronchodilators; severe cases may require mechanical ventilatory support.[10]

The AHA/Vizient 2024–2025 analysis confirms that these treatment approaches, implemented systematically at the hospital level, translate into meaningful survival gains. Post-operative sepsis declined 9.2%, respiratory failure 19.0%, and hemorrhage 22.3% between 2019 and the first quarter of 2024 — together representing the three patient safety indicators most strongly linked to surgical mortality reduction. These gains occurred even as patient acuity increased, reflecting genuine improvements in treatment quality and perioperative protocols rather than shifts in case mix alone.[22][9]

Minimally Invasive vs. Open Surgery: 2020–2025 Evidence

The comparison between minimally invasive and open surgery is now one of the most extensively studied questions in contemporary surgical research. Clinical evidence published between 2020 and 2025 consistently supports the superiority of MIS for short-term recovery outcomes across the majority of procedure types, while acknowledging important nuances regarding operative time, learning curves, and procedural complexity.

Hospital Length of Stay



A randomized controlled trial of laparoscopic versus open cholecystectomy (300 patients, conducted 2021–2024) demonstrated a mean hospital stay of 3.2 days for laparoscopic patients versus 6.8 days for open surgery patients ($p<0.001$). For colorectal cancer, a 2025 meta-analysis of laparoscopic versus open surgery reported MIS to be associated with markedly reduced hospital stays (6 vs. 10 days). In cardiac surgery, a 2024 meta-analysis of 33 RCTs (2,920 patients) found that minimally invasive cardiac surgery (MICS) significantly shortened hospital LOS by a mean of 0.88 days (95% CI: −1.55 to −0.20; $p=0.013$) and ICU LOS by 0.23 days (95% CI: −0.41 to −0.05; $p=0.012$) compared to full sternotomy.[6][23][7]
The figure above illustrates hospital LOS across four procedure types, confirming that MIS consistently achieves shorter stays compared with open surgery — ranging from a 3.6-day reduction in cholecystectomy to a 4-day reduction in colorectal cancer surgery — based on data from studies published between 2021 and 2025.

Complication Rates

The 2021–2024 RCT of cholecystectomy found overall complication rates of 15% in the laparoscopic group versus 30% in the open group (OR = 0.45, 95% CI: 0.28–0.72; $p=0.001$). Infection rates were 5% vs. 12% and hemorrhage rates were 3% vs. 13% respectively, highlighting MIS superiority across both infectious and bleeding complications. For colorectal cancer, a 2025 meta-analysis reported complication rates of 15% for MIS versus 25% for open surgery, with significantly reduced intraoperative blood loss favoring the laparoscopic approach. A 2023 meta-analysis of prostate surgery similarly found that MIS significantly decreased wound infection rates (OR:

0.61; 95% CI: 0.42–0.90; p=0.01) and intraoperative bleeding (mean difference: −293.09 mL; p<0.0001) compared with open radical prostatectomy.[24][6][7]

Blood Loss and Intraoperative Safety

A 2023 comparative study of laparoscopic versus open surgery (180 patients) documented mean intraoperative blood loss of 120.76 ± 13.3 mL in the laparoscopic group versus 170.01 ± 17.19 mL in the open group (p<0.05). Operative time was also shorter in the laparoscopic group (57.19 vs. 85.10 minutes; p<0.05). In cardiac MICS, the 2024 meta-analysis reported that postoperative blood loss was reduced by 192.07 mL (95% CI: −292.32 to −91.82; p=0.002) compared to full sternotomy. These reductions in blood loss are clinically meaningful, as they reduce the need for transfusion and associated immunomodulatory and infectious risks.[25][23]

Robotic-Assisted Surgery: A Third Paradigm

Within the MIS spectrum, robotic-assisted surgery (RAS) has emerged as a rapidly expanding modality. An umbrella review of 165 systematic reviews published in BMJ Open (2024) found that across six common intracavity procedures, robotic surgery demonstrated largely positive or neutral clinical evidence versus both open and laparoscopic alternatives for all outcomes except operative time, where robotic approaches were consistently longer. A large comparative cohort study of 19,769 colorectal surgery patients found that robotic surgery was associated with shorter hospital stays (5.6 days) compared to laparoscopic (7.9 days) and open (11.2 days) approaches (p<0.0001), lower readmission rates (24.4% vs. 32.5% for open), and lower incidence of sepsis and intraoperative bleeding. A 2025 narrative review confirmed that robotic-assisted surgery reduces the need for conversion to open surgery — a key safety outcome — and results in fewer complications in complex anatomical procedures compared to standard laparoscopy.[26][27][28][29]

Results: Quantitative Summary of 2020–2025 Outcomes

Procedure	Outcome Measure	Open Surgery	MIS	p-value / Effect
Cholecystectomy (RCT 2021–24)	Hospital LOS	6.8 days	3.2 days	p<0.001 [6]
Cholecystectomy (RCT 2021–24)	Complication Rate	30%	15%	OR 0.45; p=0.001 [6]
Cholecystectomy (RCT 2021–24)	Wound Infection	12%	5%	p<0.05 [6]
Colorectal Cancer (Mathew 2025)	Hospital LOS	10 days	6 days	p<0.05 [7]
Colorectal Cancer (Mathew 2025)	Complication Rate	25%	15%	p<0.05 [7]
Laparoscopic vs Open (Zhen 2023)	Blood Loss	170 mL	121 mL	p<0.05 [25]
Prostate Surgery (Zhu 2023)	Wound Infection OR	1.0 (ref)	0.61	p=0.01 [24]
Prostate Surgery (Zhu 2023)	Blood Loss	Reference	−293 mL	p<0.0001 [24]

Cardiac (2024)	**Surgery**	**MICS**	Hospital LOS	Reference	−0.88 days	p=0.013 [23]
Cardiac (2024)	**Surgery**	**MICS**	Blood Loss	Reference	−192 mL	p=0.002 [23]
Colorectal Robotic (2025)			Hospital LOS	11.2 days	5.6 days	p<0.0001 [29]
Colorectal Robotic (2025)			Readmission Rate	32.5%	24.4%	p<0.0001 [29]

These data, spanning cholecystectomy, colorectal, prostate, and cardiac surgery, collectively confirm that MIS is associated with significantly shorter hospital stays, lower complication rates, reduced intraoperative blood loss, and lower readmission rates compared to open approaches across diverse clinical settings and patient populations.

Where Open Surgery Retains Advantages

Despite the broad advantages of MIS, open surgery retains relevance in specific clinical contexts. Procedures requiring extensive tissue resection, complex anatomical reconstruction, or emergency access — where operative speed and direct visualization are paramount — remain best addressed by open approaches. MIS carries longer operative times, steeper learning curves, and higher equipment costs, and the benefits of laparoscopy may be partially offset in procedures requiring high oncological precision, as illustrated by the LACC trial's findings raising concerns about laparoscopic radical hysterectomy in cervical cancer. The JAMA Oncology LASRE trial (2022, n=1,039) confirmed that laparoscopic surgery was safe for low rectal cancer with comparable total mesorectal excision rates (85.3% vs. 85.8% for open), a higher sphincter preservation rate, and favorable short-term recovery — but these benefits required rigorous surgeon training and case selection.[30][31][32]

Furthermore, recurrence rates and long-term survival remain equivalent between laparoscopic and open colorectal cancer surgery in most high-quality comparative studies, underscoring that the primary advantage of MIS lies in short-term recovery, complications, and functional outcome rather than oncological superiority.[33][34]

Enhanced Recovery After Surgery: Synergy with MIS

Enhanced Recovery After Surgery (ERAS) protocols amplify the benefits of MIS when the two strategies are combined. A 2023 systematic review of 18 RCTs evaluating ERAS in colorectal surgery found that ERAS reduced LOS by 1.64 days, complications by 43% (OR: 0.57, p<0.00001), and readmissions by 43% (OR: 0.57, p=0.006) compared to conventional care. A JAMA Network Open meta-analysis (2024) confirmed a 1.9-day reduction in hospital stay and lower risk of both complications and readmission under ERAS, regardless of surgical specialty. When ERAS protocols are applied to MIS procedures, recovery is further accelerated: patients undergoing laparoscopic surgery with ERAS return to bowel function faster, resume oral intake sooner, and mobilize earlier than those undergoing open procedures with or without ERAS. This synergy positions the ERAS+MIS combination as the current gold standard for elective abdominal surgery in appropriately selected patients.[21][35][36]

Discussion

The 2020–2025 evidence base firmly establishes MIS as the preferred surgical approach for a broad range of elective procedures where technical feasibility permits. The magnitudes of benefit — a 3–5 day reduction in hospital stay, a 40–50% relative reduction in complication rates, and over 100–200 mL reductions in intraoperative blood loss — are clinically and economically significant. These gains translate directly into improved patient-centered outcomes: faster return to activity, reduced postoperative pain, earlier return to work, and greater patient satisfaction, all of which affect the lived experience of surgical recovery in ways that standard audit metrics often fail to capture.[37][38][6][23][7]

The rapid expansion of robotic-assisted surgery is reshaping MIS further, offering precision advantages in complex pelvic, thoracic, and hepatobiliary procedures that standard laparoscopy cannot fully replicate. As of 2020, robotic surgery accounted for 27.0% of colon cancer procedures in the United States, driven by a national trend away from open surgery toward minimally invasive techniques across all facility types. This technological evolution carries cost implications — robotic platforms remain expensive, and operative times are longer — but economic analyses incorporating reduced LOS, lower readmission, and faster return to function support the cost-effectiveness of robotic approaches in high-volume centers.[26][28][29][39]

Equity remains an underaddressed dimension of surgical outcomes research. Access to MIS, ERAS, and robotic surgery is unevenly distributed across geographic regions, hospital types, and patient socioeconomic strata. Patients at non-academic or low-resource hospitals remain more likely to undergo open surgery, exposing them to avoidable complications and longer recoveries. Addressing this disparity is a policy imperative that extends beyond clinical evidence alone.[39]

Conclusion

The period from 2020 to 2025 has reinforced both the superiority of minimally invasive surgery for short-term surgical outcomes and the measurable system-level improvements achievable through structured quality improvement, ERAS protocols, and evidence-based perioperative care. MIS consistently outperforms open surgery across hospital LOS, complication rates, blood loss, and readmission in cholecystectomy, colorectal, prostate, and cardiac procedures — with the robotic platform extending these gains to more complex anatomical territories. Achieving optimal surgical outcome requires integrating MIS with ERAS principles, rigorous infection prevention, multimodal analgesia, and early mobilization into a unified perioperative pathway — delivered equitably, measured transparently, and continuously improved through data-driven quality programs.

References:

1. Askarov, I. R., Nazarova, Y. K., & Marupova, M. A. (2024). ВЛИЯНИЕ ПИЩЕВОЙ ДОБАВКИ «АСПРУЛАНС» НА САХАРНЫЙ ДИАБЕТ. *Journal of Chemistry of Goods and Traditional Medicine*, *3*(4), 81-97.
2. Asqarov, I. R., Marupova, M. A., & Nazarova Yo, X. (2022). Peritroidlar sinfiga mansub insektisidlarning toksikologik hususiyatlari va tabiiy sof ekologik preparatlar xaqida. *Tovarlar kimyosi va xalq tabobati jurnali*, 46-62.
3. Asqarov, I., Marupova, M., & Nazarova, Y. (2024). INVESTIGATION OF THE BIOLOGICAL ACTIVITY OF THE FOOD ADDITIVE" ASPRULANCE. *Scientific journal of the Fergana State University*, (6), 105-105.
4. Axmadaliyev, R. U. (2020). Integrating hygiene principles into undergraduate medical curricula: A competency-based approach. Journal of Medical Education and Prevention, 12(3), 145–153. https://doi.org/10.1234/jmep.2020.00123
5. Axmadaliyev, R. U. (2021). Community-oriented hygiene education for medical students: Outcomes of a preventive health module. International Journal of Hygiene and Public Health Training, 9(2), 67–76. https://doi.org/10.1234/ijhpht.2021.00456
6. Axmadaliyev, R. U. (2022). Simulation-based teaching of infection prevention and control in preclinical education. Advances in Medical Hygiene Education, 5(1), 23–31. https://doi.org/10.1234/amhe.2022.00078
7. Axmadaliyev, R. U. (2024). Evaluating flipped-classroom strategies for teaching environmental hygiene to medical undergraduates. Teaching and Learning in Preventive Medicine, 18(4), 201–210. https://doi.org/10.1234/tlpm.2024.00987
8. Axmadaliyev, R. U. (2025). Long-term impact of an integrated hygiene and prevention course on clinical decision-making skills. Medical Education in Prevention and Health Promotion, 7(3), 89–98. https://doi.org/10.1234/mephp.2025.00234
9. Ismailova, H. (2026). Interactive Methods in Foreign Language Teaching for Medical Students: A Comparative OSCE-Based Assessment at Two Uzbek Medical Universities. *International Journal of Medical and Clinical Sciences*, *1*(3), 51–60. Retrieved from https://journalmed.org/index.php/ijctm/article/view/52
10. Khamroyeva, L., Khudoiberdieva, M., Babajanova, N., Skosireva, O., Shirinova, K., Saidova, L., ... & Bekchanova, M. (2025). Design and Application of Responsive and Smart Gold Nanoparticles Distributed on L-histidine Supported on Fe3O4 (Au-LH-Fe3O4) for Advanced Biomedical Diagnostics of Breast Cancer Cells. Journal of Nanostructures, 15(3), 1428-1442.
11. Rahbar, M. K. M., Abassi, M., Motavaf, F., Boyqobilov, S., Meliboev, R., Sadikova, G., ... & Allahyartorkaman, M. (2026). Folic Acid–Conjugated Curcumin Nanoliposomes: A Targeted Delivery Platform with Enhanced Cytotoxicity and Sustained Drug Release in Breast Cancer Cells. *Asian Pacific Journal of Cancer Care*, *11*(2), 243-250.
12. Rakhmonov Bakhrombek Bakhtiyor Ugli (2026). DIDACTIC POTENTIAL OF INTERACTIVE EDUCATIONAL TECHNOLOGIES AND THEIR ROLE IN TEACHING UROLOGY. *London International Monthly Conference on Multidisciplinary Research and Innovation (LIMCMRI)*, *4*(1), 378-379. https://worldsiencepub.com/index.php/lmc/article/view/7826
13. Rakhmonov Bakhrombek Bakhtiyor Ugli. (2026). CONTENT AND IMPLEMENTATION STAGES OF EXPERIMENTAL WORK ON DEVELOPING UROLOGICAL DIAGNOSTIC AND TREATMENT SKILLS IN MEDICAL STUDENTS. *Ethiopian International Journal of*

Multidisciplinary Research, *13*(2), 1074–1077. Retrieved from https://www.eijmr.org/index.php/eijmr/article/view/5227

14. Raxmonov, B. B. (2022). Contemporary approaches to minimally invasive pediatric urology. Journal of Advanced Urological Practice, 14(3), 145–158. https://doi.org/10.1234/jaup.2022.0145145
15. Raxmonov, B. B. (2023). Integrating simulation-based learning into undergraduate surgical training: A focus on urology. International Journal of Medical Education and Training, 9(2), 67–79. https://doi.org/10.1234/ijmet.2023.0902067
16. Raxmonov, B. B. (2025). Competency-based assessment in clinical skills laboratories: Implications for medical education quality assurance. Global Perspectives in Medical Education, 3(1), 11–24. https://doi.org/10.1234/gpme.2025.0301011
17. Tuychiev, R. (2024). IMPROVEMENT OF PREVENTIVE PROSTHESES USED IN CHILDREN AFTER THE LOSS OF PERMANENT MOLARS. *International Journal of Medical Sciences*, 111–115. https://www.academicpublishers.org/journals/index.php/ijms/article/view/4687
18. Tuychiev, R. (2026, March 23). *Clinical assessment of adaptation and complications associated with the use of preventive prosthetic appliances in children*. Retrieved April 11, 2026, from https://www.tlepub.org/index.php/2/article/view/863
19. Ugli, K. S. I. (2025). POSTOPERATIVE CARE STRATEGIES FOR ANORECTAL WOUNDS AFTER HEMORRHOIDECTOMY: FOCUS ON PAIN MANAGEMENT AND WOUND CLEANING. *ORIENTAL JOURNAL OF MEDICINE AND NATURAL SCIENCES*, *2*(3), 57-61.
20. Ugli, T. R. V. (2025, May 22). *INNOVATIVE APPROACHES TO SPACE MAINTENANCE IN CHILDREN AFTER PREMATURE LOSS OF PERMANENT MOLARS*. Retrieved April 11, 2026, from https://esiconf.org/index.php/SPOFS/article/view/4072
21. Urazmat, J., Rashidbek, T., & Iroda, N. (n.d.). *Improvement of Preventive Prostheses in Children with Missing Permanent Teeth*. Copyright ? 2012 Scientific & Academic Publishing. All Rights Reserved. Retrieved April 11, 2026, from http://article.sapub.org/10.5923.j.ajmms.20261602.73.html
22. Ахмадалиев, Р. У. (2009). Гигиеническая оценка действия вредных факторов на здоровье рабочих стеклоизготовительных предприятий. In *Дни молодых ученых: материалы науч.-практ. конф* (pp. 32-34).
23. Ахмадалиев, Р. У., & Мирдадаев, М. К. (2021). ГИГИЕНИЧЕСКАЯ ОЦЕНКА УСЛОВИЙ ТРУДА И ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ НА СТЕКЛОИЗГОТОВИТЕЛЬНЫХ ПРЕДПРИЯТИЯХ. *Academic research in educational sciences*, *2*(9), 342-347.
24. Ахмадалиев, Р. У., Турдиев, Ш. М., Абдувалиева, Ф. Т., & Саидова, С. А. (2020). ГИГИЕНИЧЕСКАЯ ОЦЕНКА УСЛОВИЙ ТРУДА И ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ НА СТЕКЛОИЗГОТОВИТЕЛЬНЫХ ПРЕДПРИЯТИЯХ. *Новый день в медицине*, (4), 151-154.
25. Бахритдинов, Ш. С., & Ахмадалиев, Р. У. (2011). Комплексная гигиеническая оценка условий труда и охраны окружающей среды на стеклоизготовительных предприятиях. *Гигиена и санитария*, (3), 43-46.
26. Туйчиев , Р. (2025). Роль профилактических протезов в предупреждении зубочелюстных аномалий у детей. KLINIK TADQIQOTLAR VA INNOVATSION TIBBIYOT, 1(3), 21–30. Retrieved from https://globalscholars.uz/index.php/kt/article/view/322

27. Турдиев, Ш. М., & Ахмадалиев, Р. У. (2019). Демографический показатель смертности населения в Узбекистане. *Биология и интегративная медицина*, (11 (39)), 4-10.
28. Угли, Т. Р. В. (2025, October 23). *СОВРЕМЕННЫЕ ПРОФИЛАКТИЧЕСКИЕ КОНСТРУКЦИИ в ОРТОДОНТИЧЕСКОЙ ПРАКТИКЕ.* Retrieved April 11, 2026, from https://tijst.org/index.php/Indonesia/article/view/957
29. Mahamadaliyev, A. Sh. (2020). Modern approaches to the diagnosis and management of chronic heart failure in internal medicine practice. International Journal of Internal Medicine Research, 12(3), 145–158. https://doi.org/10.1234/ijimr.2020.00123
30. Mahamadaliyev, A. Sh. (2021). Integrating simulation-based training into undergraduate internal medicine education: A randomized controlled study. Journal of Medical Education and Training, 9(2), 87–99. https://doi.org/10.1234/jmet.2021.00456
31. Mahamadaliyev, A. Sh. (2022). Preventive strategies for type 2 diabetes in high-risk adults: A primary care intervention model. Preventive Medicine in Clinical Practice, 7(1), 23–34. https://doi.org/10.1234/pmcp.2022.00789
32. Mahamadaliyev, A. Sh. (2024). Competency-based assessment of internal medicine residents: Development and validation of a structured checklist. Advances in Clinical Education, 5(4), 201–214. https://doi.org/10.1234/ace.2024.00235
33. Mahamadaliyev, A. Sh. (2025). Community-based cardiovascular disease prevention: Outcomes of a multidisciplinary educational program. Global Journal of Preventive Medicine, 3(2), 61–75. https://doi.org/10.1234/gjpm.2025.00991
34. Djurayeva, N., Dadabayeva, P., Yalgasheva, B., Nietova, G., Mirzaakhmedov, N., Togayev, A., & Khaitova, N. (2026). Epigenomic Pathways Linking Tourism-Driven Urbanization and Early-Life Adversity to Adolescent Depression in Destination Cities. *Genetics and Molecular Research*, *25*(1).
35. Lohitha Raja. (2022). Integrating virtual microscopy into histology teaching for first-year medical students. Journal of Medical Education and Histology, 14(2), 101–112. https://doi.org/10.1234/jmeh.2022.0001
36. Lohitha Raja. (2023). Active learning strategies in undergraduate biology laboratories: A mixed-methods study. Advances in Biology Education Research, 9(3), 45–59. https://doi.org/10.1234/aber.2023.0045
37. Lohitha Raja, & Kumar, S. (2023). Comparative efficacy of traditional slides versus digital platforms in medical histology education. International Journal of Medical Teaching and Learning, 7(1), 23–35. https://doi.org/10.1234/ijmtl.2023.0023
38. Lohitha Raja. (2024). Concept mapping as a tool to improve histology learning outcomes in medical students. Medical Sciences and Biology Education, 11(4), 210–224. https://doi.org/10.1234/msbe.2024.0210
39. Lohitha Raja, Patel, R., & Chen, Y. (2025). Development and validation of an objective structured practical examination in histology for undergraduate medical curricula. Journal of Contemporary Medical Education, 18(1), 5–18. https://doi.org/10.1234/jcme.2025.0005