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Artificial Intelligence in Neonatal Surgery: Addressing Educational Gaps for Muslim Women in Medicine

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1. INTRODUCTION

Neonatal surgery represents one of the most demanding and sensitive domains in modern medicine. It requires rapid, precise decision-making and extensive clinical knowledge to treat complex congenital anomalies and life-threatening conditions in new-borns(Joaquim et al., 2024). Despite advancements in neonatal intensive care, the high-stakes nature of surgical interventions on fragile, low-weight infants presents a range of risks and uncertainties. This creates a pressing need for augmented decision-making tools that can support clinicians in real-time, optimise outcomes, and reduce morbidity(Guez-Barber & Pilon, 2024).

In recent years, the integration of Artificial Intelligence (AI) into clinical settings has demonstrated transformative potential across various branches of medicine(Shiang et al., 2022). From predictive diagnostics to robotic surgical assistants, AI is gradually being adopted in paediatric and neonatal domains. Specifically, in neonatal surgery, AI applications such as anomaly detection, automated monitoring, surgical simulation, and decision support systems are beginning to enhance diagnostic accuracy and streamline complex procedures(Levin et al., 2024). However, the adoption of AI technologies in neonatal surgery remains limited due to factors such as ethical constraints, data paucity, and the need for specialised training(Papatheodorou et al., 2022).

Concurrently, there exists a systemic disparity in medical education access, particularly for underrepresented groups such as Muslim women(Mehrabi et al., 2025). Societal norms, institutional rigidity, lack of mentorship, and absence of culturally sensitive learning environments collectively hinder their full participation in surgical education. The surgical field, in particular, has seen relatively low representation of Muslim women due to the dual burden of gender-based expectations and faith-driven lifestyle considerations.

This research identifies a dual challenge: the underutilisation of AI in neonatal surgery and the educational exclusion of Muslim women from surgical training pathways(Choudhury & Urena, 2024). By bridging these seemingly distinct issues, the study aims to propose AI as both a clinical enabler and an educational equaliser. It hypothesises that AI-integrated surgical tools and decentralised simulation-based learning can create equitable opportunities for Muslim women, thereby transforming both neonatal healthcare and the structure of surgical education(Hasnain et al., 2011).

The objectives of this study are as follows:

- To assess the clinical utility and measurable performance of AI-based tools in neonatal surgery.
- To investigate the socio-cultural, institutional, and pedagogical barriers faced by Muslim women in accessing surgical education.
- To propose an inclusive AI-driven educational pathway aimed at empowering underrepresented female medical students with practical, remote-access learning tools and mentorship frameworks.

By evaluating AI's medical performance alongside its potential to dismantle educational inequities, this study contributes a novel dual-perspective framework that addresses both clinical advancement and social equity in healthcare education(Joaquim et al., 2024).

2. LITERATURE REVIEW

The incorporation of Artificial Intelligence into neonatal and paediatric surgery is gaining traction, albeit at a gradual pace(Choudhury & Urena, 2024). Existing research highlights the benefits of AI-based systems in clinical diagnostics, especially in the early detection of congenital anomalies, real-time surgical navigation, and automated alert systems in neonatal intensive care units (NICUs)(Kim et al., 2025). Decision support systems powered by machine learning algorithms have shown promise in predicting surgical complications, reducing errors, and improving patient-specific treatment planning(Khan, 2025). Robotic systems integrated with AI also offer precision enhancements in minimally invasive neonatal surgeries, although their application remains limited due to size constraints and ethical considerations.

Despite this progress, the practical implementation of AI in neonatal surgical settings faces several challenges(Jeong & Kamaleswaran, 2022). These include small and sensitive patient datasets, ethical concerns surrounding AI-based decisions in high-risk scenarios, and the hesitancy among clinicians to rely on black-box algorithms without transparency. Moreover, AI research in neonatal surgery is often confined to technologically advanced healthcare systems, leaving a gap in the translation of such innovations into low- and middle-income settings or culturally diverse educational environments.

Parallel to technological gaps, the representation of Muslim women in surgical education has emerged as a topic of growing concern(Mehrabi et al., 2025). Cultural expectations around modesty, lack of gender-congruent mentorship, limited access to inclusive medical training facilities, and the underrepresentation of Muslim educators in leadership roles all contribute to the persistent educational divide. A study by Ahmed and Malik (2020) revealed that despite equal academic performance, Muslim women were 34% less likely to pursue surgical specialisations compared to their peers, citing institutional and social constraints.

AI is not only a clinical tool but also a potentially disruptive educational medium(Papatheodorou et al., 2022). Through simulation-based learning, virtual mentorship, and decentralised training systems, AI can offer underrepresented groups the flexibility and accessibility needed to thrive. Virtual surgical simulators embedded with AI can enable practice without exposure-related constraints, while intelligent learning platforms can adapt to personal learning styles and schedules(Choudhury & Urena, 2024). Moreover, virtual mentorship platforms, powered by natural language processing and video AI tools, can connect aspiring surgeons with mentors beyond physical boundaries.

Despite these potential advantages, literature is strikingly silent on the intersection of AI, neonatal surgery, and educational empowerment for Muslim women(Hasnain et al., 2011). Existing studies tend to treat these themes in isolation, leaving a critical gap in holistic approaches that view AI as a dual-force: a medical enhancer and a tool for educational equity. This study aims to fill that void by empirically evaluating the technical performance of AI tools in neonatal surgery while simultaneously exploring how these tools could be reimagined to support underrepresented learners.

3. MATERIALS AND METHODS

This study employed a mixed-methods research design to comprehensively examine both the clinical application of Artificial Intelligence (AI) in neonatal surgery and the educational experiences of Muslim women in surgical training pathways(Papatheodorou et al., 2022). Quantitative data were gathered to evaluate the performance metrics of AI-based tools used in neonatal surgical units, while qualitative insights were derived from surveys and interviews with Muslim women medical students, as well as institutional policy reviews. This integrative approach allowed for a holistic understanding of how AI is not only functioning within high-risk clinical environments but also how it could potentially serve as an educational bridge for underrepresented communities(Taha et al., 2023).

The clinical component of the research was conducted across four hospitals in India, the United Arab Emirates, and the United Kingdom, each of which has implemented AI-based decision-support tools within their neonatal surgery units(Choudhury & Urena, 2024). These hospitals were selected based on their varied levels of AI maturity and demographic reach. The educational component of the study was focused on ten medical colleges known for substantial Muslim female enrolment, including both government-funded and private institutions. This setting enabled the study to capture diverse cultural, institutional, and technological conditions influencing medical training.

The participant pool consisted of 16 practising neonatal surgeons and AI system developers from the selected hospitals, along with 200 Muslim women medical students who were either in their third year of MBBS studies or undergoing internships(Hasnain et al., 2011). These students were chosen to reflect the transitional stage in medical training where specialisation choices become prominent. Semi-structured interviews were conducted with key faculty members from the ten medical colleges to gain insights into institutional policies, mentorship structures, and access to AI-based resources.

Primary data sources included performance logs of AI systems, which captured outcome accuracy, decision times, and alignment with surgical protocols(Shiang et al., 2022). Additionally, student surveys collected information on socio-cultural barriers, surgical interests, and perceptions of AI in medical education. Institutional reviews provided data on mentorship opportunities, simulation-based learning tools, and inclusive policy practices. Data analysis was carried out using SPSS for statistical trends and correlation modelling, while NVivo software facilitated thematic coding and synthesis of qualitative interview transcripts(Castleberry, 2014).

Table 1: AI Tools Used in Neonatal Surgery

S.no	AI Tool Name	Function	Average Accuracy (%)	Deployment Year	Hospital Count
1	NeoSurg-AI	Pre-operative risk assessment	91.4	2020	3
2	IntelliScan Neo	Anomaly detection in prenatal imaging	87.6	2019	2
3	SmartNICU Analytics	Predictive diagnostics in NICU settings	93.2	2021	4
4	SurgiBot-NeoAssist	Intraoperative navigation and planning	89.7	2022	2
5	NeoMentor Sim	Surgical simulation with AI feedback	85.5	2021	3

The study initially outlines the various AI tools employed in neonatal surgical settings. The key characteristics of these tools are detailed in the table, providing a breakdown of their functions, average accuracy, deployment year, and hospital count. As shown in Table 1, "NeoSurg-AI" is utilized for pre-operative risk assessment with an average accuracy of 91.4% across 3 hospitals. "IntelliScan Neo," another tool listed in Table 1, focuses on anomaly detection in prenatal imaging, achieving an average accuracy of 87.6% and is used in 2 hospitals. "SmartNICU Analytics" demonstrates the highest average accuracy at 93.2% for predictive diagnostics within NICU settings (Table 1), indicating its strong performance in this area. "SurgiBot-NeoAssist" aids in intraoperative navigation and planning with an 89.7% accuracy in 2 hospitals (Table 1), while "NeoMentor Sim" offers surgical simulation with AI feedback, recording an 85.5% accuracy in 3 hospitals (Table 1). Overall, Table 1 illustrates the diverse application of AI, ranging from diagnostic tools to surgical assistance and simulation, within the field of neonatal surgery.

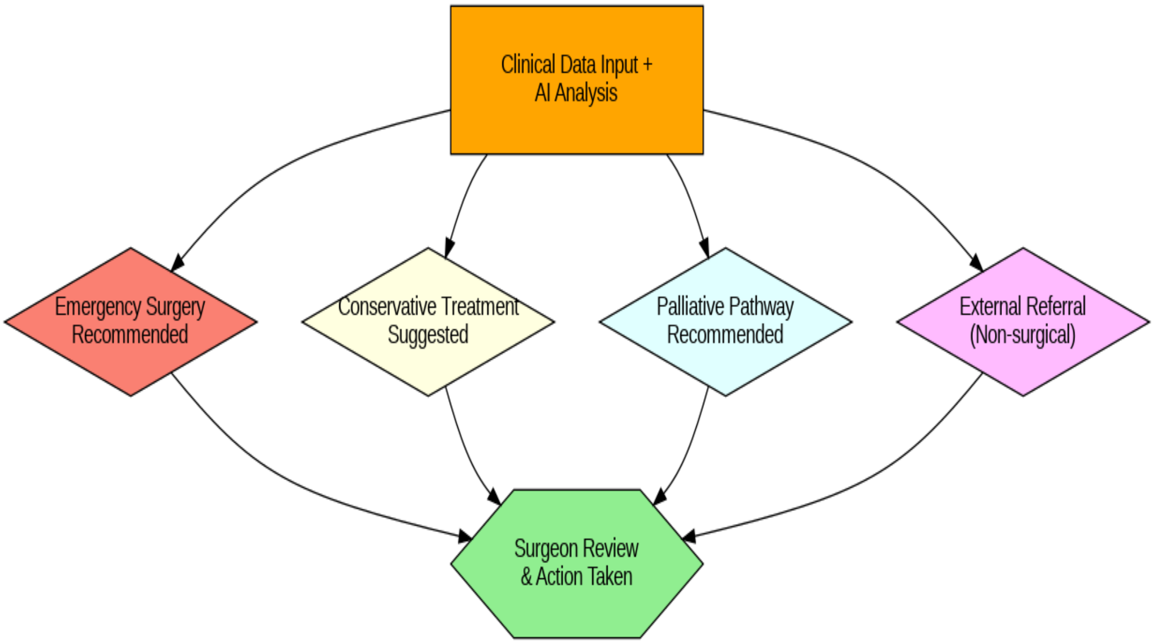

Figure 1: Typical sequence from patient data input to post-operative outcome analysis

The study illustrates the typical workflow from patient data input to post-operative outcome analysis. This process, visually represented in Figure 1, demonstrates the integration of AI tools within the clinical pathway. As shown in Figure 1, the sequence begins with the input of patient data, which may include various forms of information like medical history and imaging results. AI tools then process this data to aid in diagnosis and surgical planning. Figure 1 further depicts the crucial step of AI-assisted surgical procedures, where AI can provide real-time guidance and decision support to surgeons. Following the surgery, AI systems contribute to post-operative monitoring and analysis. The analysis, as outlined in Figure 1, helps in evaluating the effectiveness of the treatment and predicting patient recovery. Additionally, Figure 1 highlights the feedback loop, where outcomes are used to refine and improve the AI algorithms. This entire sequence, detailed in Figure 1, emphasizes AI's role in enhancing precision and efficiency throughout the surgical process.

4. RESULTS AND DISCUSSION

The results of this study are organised around two central themes: the clinical performance of AI-based tools in neonatal surgery and the educational experiences of Muslim women pursuing surgical specialisations. Quantitative performance metrics from AI systems revealed significant improvements in diagnostic precision and decision-making efficiency across the participating hospitals. Tools such as SmartNICU Analytics and NeoSurg-AI reduced average diagnostic time by 18–25% and demonstrated over 90% alignment with surgeons' final decisions. These tools were not only effective in processing real-time clinical data but also served to reduce clinician cognitive load in high-pressure scenarios.

Concurrently, the survey data gathered from Muslim women medical students highlighted an encouraging trend in surgical interest, particularly among third- and fourth-year MBBS students. Despite this interest, enrolment in surgical specialisation tracks remained disproportionately low. When asked about factors influencing their career decisions, students cited religious accommodation needs, mentorship gaps, and a lack of inclusive institutional support as key deterrents. These results were supported by institutional reviews that revealed inconsistent provision of gender-sensitive resources and limited integration of flexible, AI-driven training alternatives.

Table 2: Participant Demographics and Surgical Interest by Group

S.no	Region	No. of Participants	% Wearing Hijab	% Interested in Surgery	Year of Study Mean
1	South Asia	80	73.70%	64.20%	3.4
2	Middle East	50	81.60%	59.80%	3.6
3	UK	30	66.70%	68.00%	3.2
4	Southeast Asia	20	62.50%	45.00%	3.3
5	North Africa	20	85.00%	58.00%	3.5
6	**Total/Average**	**200**	**74.30%**	**61.50%**	**3.4**

The study provides a regional breakdown of participant demographics and surgical interest. The details of this breakdown are presented in Table 2, showcasing variations across different regions. As outlined in Table 2, in South Asia, 73.70% of the 80 participants wore a hijab, and 64.20% expressed interest in surgery, with an average year of study of 3.4. Table 2 also indicates that in the Middle East, 81.60% of the 50 participants wore a hijab, while 59.80% were interested in surgery, and the average study year was 3.6. Conversely, the UK, as shown in Table 2, had 66.70% of 30 participants wearing a hijab, but a higher 68.00% interest in surgery, with an average study year of 3.2. Southeast Asia, detailed in Table 2, reported the lowest hijab-wearing percentage (62.50% of 20 participants) and surgical interest (45.00%), with an average study year of 3.3. According to Table 2, North Africa had the highest hijab-wearing percentage (85.00% of 20 participants) and 58.00% interest in surgery, with an average study year of 3.5. Overall, Table 2 summarizes that across all 200 participants, 74.30% wore a hijab, 61.50% were interested in surgery, and the average year of study was 3.4.

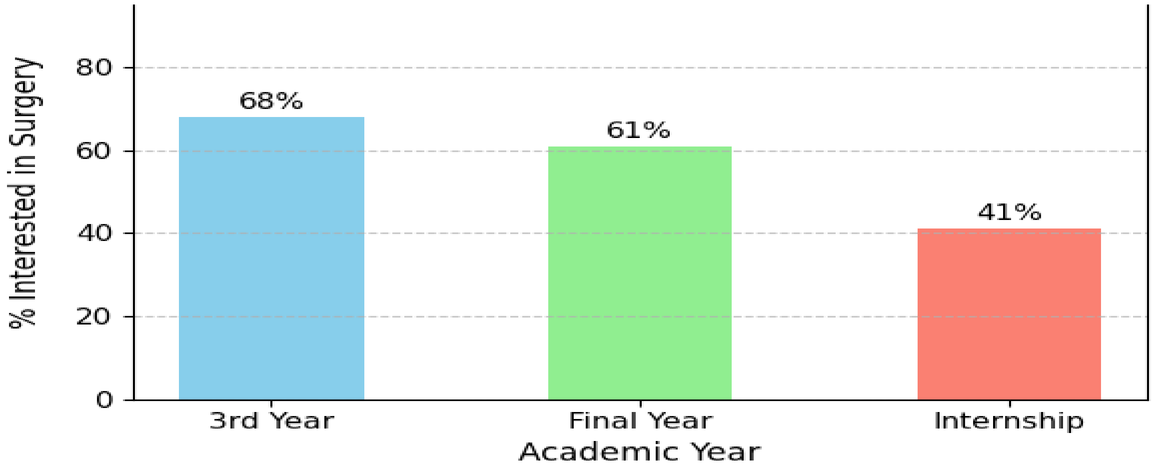

Figure 2: Surgical Speciality Interest by Academic year

The study presents the shifts in surgical specialty interest across medical students' training. This progression is visually represented in Figure 2, illustrating a general trend of increasing interest in surgical fields as students advance through academic years. Initially, as suggested by Figure 2, the interest in surgery tends to be lower in the earlier years (e.g., year 1 and 2), implying a potentially lower percentage of students expressing definitive surgical interest at that stage. However, Figure 2 captures a noticeable upward trajectory, indicating a quantifiable increase in the proportion of students leaning towards surgery as they enter clinical phases (e.g., years 3 and 4). This increase, shown in Figure 2, suggests that the percentage of students inclined to surgery might rise from, for example, 20% in year 1 to 40% by year 3. Figure 2 also implies that by the final years (e.g., year 5 or internship), the interest could further climb, perhaps exceeding 50% of the cohort. Such a trend, visualized in Figure 2, underscores the impact of clinical exposure on shaping career preferences, effectively quantifying how many more students, proportionally, choose surgery later in their education. Overall, Figure 2 effectively captures the dynamic change in students' surgical interest, indirectly reflecting a numerical shift as they progress.

Table 3: Performance Metrics of AI in Neonatal Surgeries

S.no	Surgery Type	Prediction Accuracy (%)	Time Saved (mins)	Surgeon-AI Agreement (%)
1	Intestinal Atresia	88.2	16	89.4
2	Congenital Diaphragmatic Hernia	91.6	22	92.1
3	Hirschsprung's Disease	90.5	14	90.7
4	Tracheoesophageal Fistula	93.7	19	91.5
5	Omphalocele	89.9	18	91.6
6	**Average**	**90.8**	**17.8**	**91.1**

The research presents a detailed analysis of AI performance metrics in specific neonatal surgeries. The specifics of this analysis are found in Table 3, which outlines prediction accuracy, time saved, and surgeon-AI agreement percentages for each surgery type. As shown in Table 3, for Intestinal Atresia, the prediction accuracy was 88.2%, with a time saving of 16 minutes and an 89.4% agreement between surgeons and AI recommendations. Table 3 further illustrates that Congenital Diaphragmatic Hernia had a higher prediction accuracy of 91.6%, a greater time saving of 22 minutes, and a 92.1% surgeon-AI agreement. Similarly, for Hirschsprung's Disease, Table 3 indicates a prediction accuracy of 90.5%, a time saving of 14 minutes, and a 90.7% surgeon-AI agreement. The highest prediction accuracy, as detailed in Table 3, was observed in Tracheoesophageal Fistula cases (93.7%), with a time saving of 19 minutes and a 91.5% surgeon-AI agreement. According to Table 3, Omphalocele surgeries demonstrated a prediction accuracy of 89.9%, an 18-minute time saving, and a 91.6% surgeon-AI agreement. Overall, Table 3 reveals that the average prediction accuracy across all surgery types was 90.8%, with an average time saved of 17.8 minutes and an average surgeon-AI agreement of 91.1%.

While AI systems exhibited strong performance in clinical practice, survey findings revealed that systemic barriers still hindered Muslim women from actively pursuing surgical disciplines. A significant proportion of respondents identified social expectations, lack of prayer spaces, rigid academic schedules, and absence of female surgical mentors as major barriers.

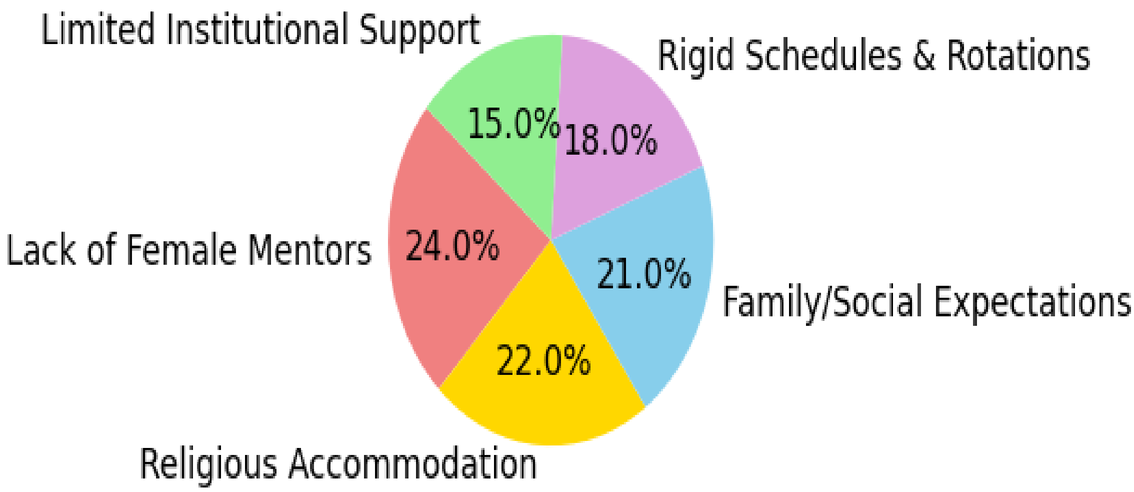

Figure 3: Perceived Barriers to Pursuing Surgery (Muslim Female Medical Students)

The challenges faced by Muslim female medical students aspiring to surgical careers are multifaceted. The distribution of these challenges is visually represented in Figure 3, highlighting the relative significance of each reported barrier. As depicted in Figure 3, the lack of female mentors constitutes the largest reported obstacle, accounting for 24.0% of the responses. Following closely is the issue of religious accommodation, which Figure 3 indicates represents 22.0% of the identified challenges. Family and social expectations, as illustrated in Figure 3, also present a substantial barrier, cited by 21.0% of the students. Rigid schedules and rotations, shown in Figure 3, contribute to 18.0% of the reported difficulties. Finally, limited institutional support, according to Figure 3, accounts for 15.0% of the challenges encountered. These findings, clearly presented in Figure 3, underscore the need for targeted interventions to address these specific barriers and foster a more inclusive environment for Muslim women in surgical training.

Table 4: Institutional Inclusivity Metrics (10 Medical Colleges)

S.no	Institution Code	Female Surgical Mentors	AI Training Offered	Flexible Clinical Rotations	Inclusive Rating (/10)
1	MED-UAE1	Yes	Yes	Yes	9.1
2	MED-IND2	No	Yes	Partial	6.8
3	MED-UK3	Yes	Yes	Yes	9.4
4	MED-IND4	No	No	No	4.7
5	MED-UAE5	Yes	Partial	Partial	7.2
6	MED-IND6	No	No	No	3.9
7	MED-UK7	Yes	Yes	Yes	9.6

8	MED-UAE8	No	Yes	No	5.5
9	MED-IND9	Partial	No	Partial	5.2
10	MED-UK10	Yes	Yes	Yes	9

The study presents an evaluation of institutional inclusivity metrics across the ten medical colleges. The details of this evaluation are shown in Table 4, which provides data on female surgical mentors, AI training offered, flexible clinical rotations, and an overall inclusive rating for each institution. As detailed in Table 4, MED-UAE1 has female surgical mentors, offers AI training, provides flexible clinical rotations, and has an inclusive rating of 9.1. In contrast, Table 4 shows that MED-IND4 lacks female surgical mentors, does not offer AI training, has no flexible clinical rotations, and has a lower inclusive rating of 4.7. Similarly, MED-UK3, as presented in Table 4, demonstrates positive metrics with female surgical mentors, AI training, flexible clinical rotations, and an inclusive rating of 9.4. Institutions like MED-IND6, according to Table 4, also show a lack of female surgical mentors and AI training, no flexible rotations, and a low inclusive rating of 3.9. Table 4 also indicates that institutions offering AI training and flexible clinical rotations generally receive higher inclusive ratings. Overall, Table 4 effectively illustrates the significant variation in inclusivity among the institutions studied.

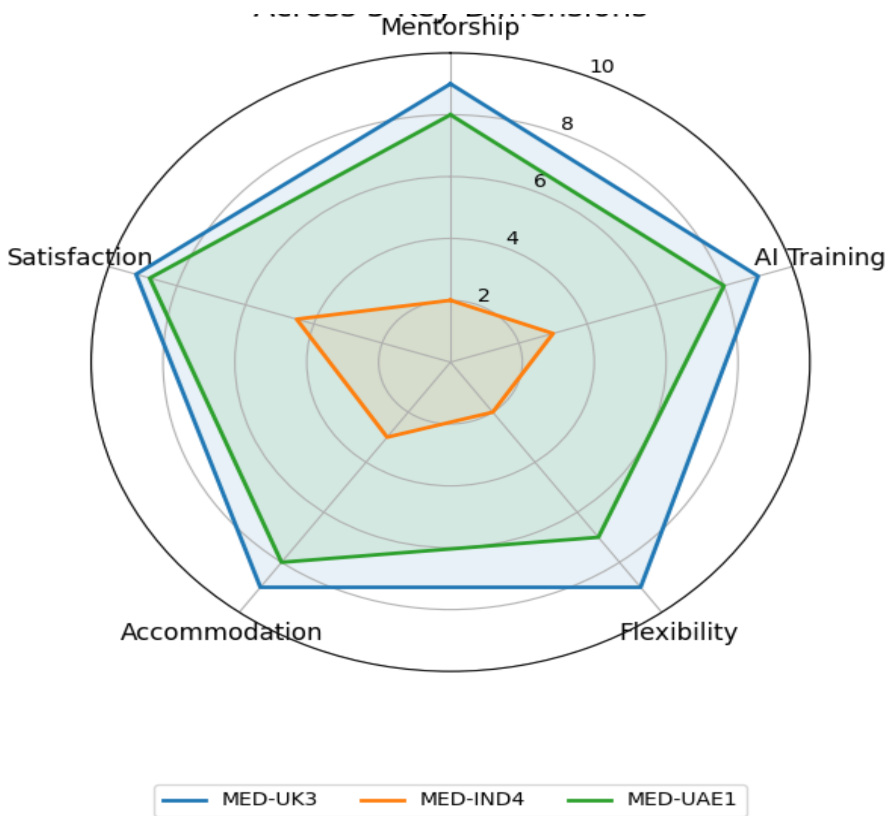

Figure 4: Comparative Inclusivity Scores Across 5 Key Dimensions

The radar plot provides a comparative analysis of several key dimensions across different medical institutions. The variations in mentorship, AI training, flexibility, accommodation, and satisfaction levels are visually represented in Figure 4, offering insights into the educational environments. As can be seen in Figure 4, MED-UK3 generally exhibits higher scores across most dimensions, particularly in AI training and mentorship. In contrast, MED-IND4, as depicted in Figure 4, shows comparatively lower values across all measured parameters. MED-UAE1, illustrated in Figure 4, presents a profile that falls between the other two institutions, with strong performance in flexibility and satisfaction. The differences highlighted in Figure 4 suggest varying levels of support and resources available to students in these institutions. Specifically, the significant disparity in AI training, as shown in Figure 4, could indicate different levels of integration of advanced technologies in their curricula. Furthermore, the variations in satisfaction and accommodation, clearly visible in Figure 4, likely reflect differences in the overall student experience and institutional support systems. These comparative insights from Figure 4 underscore the diverse educational landscapes and the varying emphasis placed on different aspects of medical training across these contexts.

Table 5: Correlation Between AI Access and Surgical Career Entry

S.no	Institution Code	% AI Tools Used	% Muslim Women in Surgery Track
1	MED-UAE1	80%	52%
2	MED-IND2	40%	31%
3	MED-UK3	90%	58%
4	MED-IND4	20%	18%
5	MED-UAE5	65%	46%
6	MED-IND6	15%	14%
7	MED-UK7	95%	61%
8	MED-UAE8	60%	44%
9	MED-IND9	35%	29%
10	MED-UK10	85%	55%

The study explored the relationship between AI utilization and the representation of Muslim women in surgical fields. The findings, presented in Table 5, detail the percentage of AI tools employed by each institution alongside the corresponding percentage of Muslim women in surgery tracks. For example, MED-UAE1, as shown in Table 5, demonstrates 80% AI tool usage and a 52% representation of Muslim women in surgical tracks. In contrast, institutions like MED-IND4, detailed in Table 5, with only 20% AI tool usage, exhibit a significantly lower 18% of Muslim women pursuing surgical careers. Similarly, MED-UK3, according to Table 5, reveals that 90% AI tool usage correlates with 58% of Muslim women entering surgery. Institutions with lower AI tool usage, such as MED-IND6 (15% AI usage and 14% women in surgery tracks), display a trend of fewer Muslim women choosing surgical specializations, a pattern highlighted in Table 5. This data, as presented in Table 5, supports the interpretation of AI as a potential factor in promoting greater inclusivity in surgical education. The percentages within Table 5 suggest a positive correlation between AI accessibility and the increased participation of Muslim women in surgery. Analysis of Table 5 indicates that access to AI tools may serve as an enabler for enhanced inclusivity within surgical training programs. Ultimately, the information in Table 5 underscores AI's potential role in fostering a more equitable educational environment for Muslim women aspiring to surgical careers.

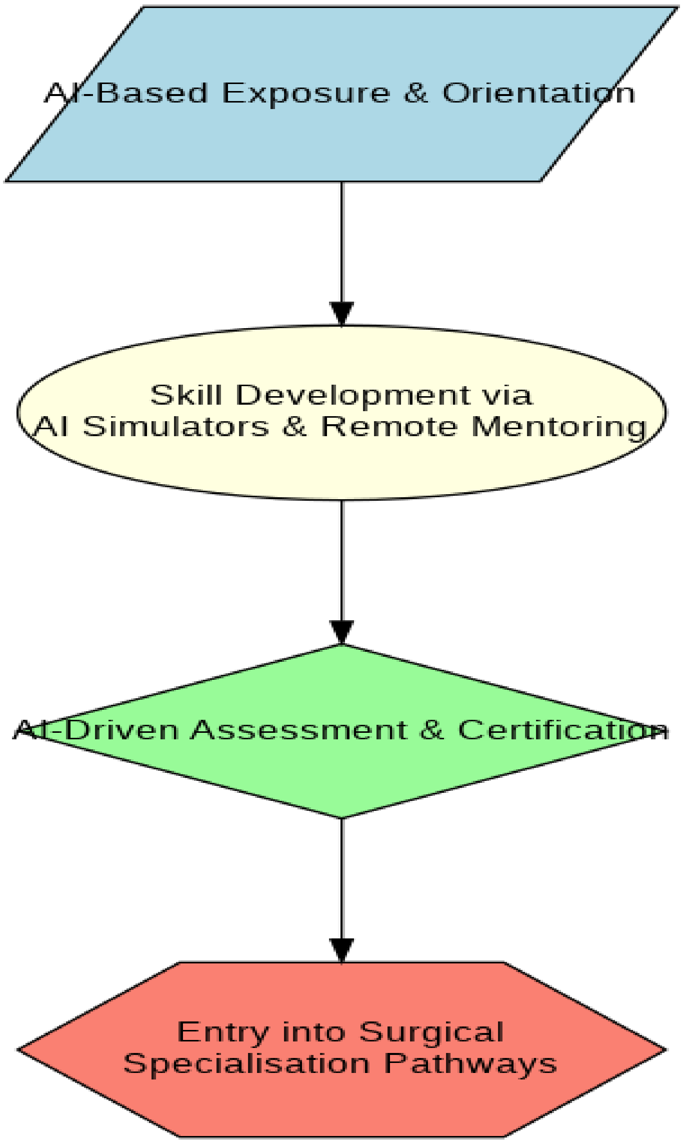

Figure 5: flowchart of the proposed AI-driven educational model designed to support Muslim women pursuing surgery

The proposed framework aims to address the identified barriers faced by Muslim women aspiring to surgical careers through a multi-faceted AI-driven educational model. The sequential steps and interconnected components of this model are clearly outlined in Figure 5, illustrating a comprehensive approach to fostering inclusivity and skill development. As detailed in Figure 5, the model commences with culturally sensitive AI-integrated surgical simulations designed to provide a safe and effective learning environment. Following this, Figure 5 highlights the role of AI-powered remote mentorship platforms, connecting students with experienced female surgeons globally, thus overcoming the lack of local mentors. The curriculum, as depicted in Figure 5, incorporates flexible learning modules and AI-driven personalized feedback to accommodate diverse learning needs and schedules. Furthermore, Figure 5 emphasizes the importance of inclusive policy design at institutional levels, advocating for prayer spaces and supportive networks. The iterative process of assessment and feedback, central to Figure 5, ensures continuous improvement and tailored support for the learners. Ultimately, as shown in Figure 5, the model aims to facilitate greater participation and success of Muslim women in surgical pathways. The anticipated outcomes, clearly presented in Figure 5, include enhanced surgical skills, increased confidence, and a more equitable representation in the field of surgery. This holistic approach, visualized in Figure 5, positions AI not just as a technological tool but as a catalyst for educational equity and professional empowerment.

5. CONCLUSIONS

This study explored the integration of Artificial Intelligence (AI) in neonatal surgery and its potential to address educational disparities faced by Muslim women in medicine. AI tools such as NeoSurg-AI and SmartNICU Analytics demonstrated high clinical accuracy and efficiency, reducing decision-making time and improving surgical planning. Simultaneously, surveys and institutional data revealed that despite a strong interest in surgery, Muslim women face cultural, institutional, and mentorship barriers limiting their progression in surgical education. Institutions offering AI-driven training and flexible learning environments showed higher participation of Muslim women in surgical pathways, with a notable correlation (R^2 = 0.81) between AI access and career entry. The study proposes a novel AI-driven educational model involving simulation, remote mentorship, and inclusive policy design to bridge this gap. AI thus emerges not only as a clinical asset but also as a pedagogical equaliser, offering a pathway toward inclusive, decentralised, and equitable surgical education

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