


The effect of deploying non-physician anaesthesia providers on surgical access and capacity across Nepal's primary and secondary government hospitals: a quasi-experimental mixed methods study

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ABSTRACT

Background The lack of skilled healthcare workers limits access to surgical care, with the greatest disparities in low- and middle-income countries. In Nepal, the 1-year anaesthesia assistant (AA) programme trains non-physician cadres in anaesthesia delivery to address this gap. We evaluated the deployment of AAs in primary and secondary government hospitals in Nepal during 2008/2009 to 2023/2024 on hospitals' ability to perform any major surgery and the number of major surgeries performed.

Methods Quasi-experimental mixed methods were employed. A two-way fixed effects regression model was used to assess surgery availability, and a staggered difference-in-difference approach was used to estimate the average treatment effect of AA deployment on surgical volume. Qualitative interviews were conducted in seven purposefully sampled hospitals to expand contextual factors not captured in the quantitative data. Results were triangulated.

Results Of 98 government hospitals, 84 (85.7%) received an AA during the study period, contributing 330 pre-AA and 651 post-AA hospital-year observations, defined as a hospital's major surgery data in a given year. Hospitals were 45.4 times more likely to be performing any major surgery after AA deployment (adjusted OR (aOR)=45.40, 95% CI 23.48 to 92.15). AA deployment was associated with a threefold increase in the odds of performing Caesarean sections (CSs) compared with non-CS major surgeries (aOR=3.46; 95% CI 3.03 to 4.07). Among hospitals performing major surgery, hospitals performed an average of 99.94 (average treatment effect on the treated (ATT)=99.94, 95% CI 45.90 to 153.98) additional major surgeries per year after AA deployment. Qualitative interviews highlighted AAs' role expanding surgical services by enabling critical procedures, reducing referrals, increasing equitable surgical access and enhancing team efficiency.

Conclusion AAs appear to enhance hospitals' ability to perform major surgeries, specifically CSs, while decreasing patient referrals and increasing surgical capacity. These results underscore the role of non-

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The *Lancet Commission on Global Surgery* identified workforce shortages as a major constraint on surgical access in low- and middle-income countries (LMICs), particularly in rural settings.
- ⇒ To address this shortage of anaesthesia providers, often a rate-limiting step of surgical care, non-physician anaesthesia providers (NPAPs) are commonly deployed to provide anaesthesia services in rural hospitals. Despite the widespread reliance on NPAPs in LMICs, to our knowledge, no studies have quantitatively evaluated their impact on surgical access or capacity.

physician anaesthesia providers in surgical access in resource-limited settings.

INTRODUCTION

Globally, 5 billion people lack access to safe surgery and anaesthesia care according to the *Lancet Commission on Global Surgery*.¹ This disproportionately burdens low- and middle-income countries (LMICs), where it is estimated that 9 in 10 people are unable to access safe surgical care.¹ In Nepal, data shows that access to safe surgery would decrease avoidable deaths by 23%.² This can be seen in Nepal's maternal mortality ratio, one of the highest in Asia, due in part to preventable obstetrical complications and a lack of specialised doctors.²

Lack of human resources (HRs) remains a significant barrier to safe surgical care in LMICs, which despite having 48% of the global population, only have 15% of anaesthesiologists.³ The *Lancet Commission on Global*

WHAT THIS STUDY ADDS

- ⇒ This study evaluates the impact of deploying NPAPs on surgical access and capacity in Nepal's peripheral government hospitals.
- ⇒ Using a quasi-experimental difference-in-difference design with 15 years of longitudinal hospital data, we quantified the effect of anaesthesia assistant deployment on a hospital's ability to perform major surgeries and the annual volume of procedures conducted once a hospital could perform any major surgeries.
- ⇒ To our knowledge, this is the first study to rigorously evaluate the impact of NPAPs on surgical capacity in low-resource settings using a robust quasi-experimental mixed-methods approach.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ This study provides new, quantified evidence that can inform national surgical workforce policy in Nepal and other LMICs facing shortages of specialist anaesthesia providers.
- ⇒ It demonstrates that NPAPs are filling an unmet need and can increase surgical access and volume in rural and underserved settings.
- ⇒ More broadly, this research underscores the need to rigorously evaluate task-shifting programmes not only for feasibility, but also for measurable impact on service delivery, and provides a model that may be applicable across other countries with similar workforce gaps.

Surgery set the 2030 target for a specialist surgeon, anaesthesiologist and obstetrician physician ratio (SAO) of 20 per 100 000.^{3 4} As of 2023, Nepal's rural specialist SAO was 0.4 per 100 000 where it is estimated that at least 2.4 million people lack access to necessary surgical care during their lifetimes.⁵ To address this, non-physician anaesthesia providers (NPAPs) task-shifting initiatives have been developed to train non-physician cadres to provide anaesthesia.⁶ While several studies described the prevalence of NPAPs, and a few reported improved anaesthesia capacities or increased surgical volume in multicountry assessments, most lacked quantitative evaluations.⁶⁻¹⁰ One study attempted to measure the impact of NPAPs on surgical volume, though it did not quantify the association.⁷

This study seeks to quantify NPAP impact on surgical volumes. The anaesthesia assistant (AA) programme is a task-shifting initiative to train health assistants (mid-level paramedics with 3 years in general medicine) or nurses to perform anaesthesia by the Nick Simons Institute and the Government of Nepal's Ministry of Health and Population (MoHP). The cadre is trained to provide anaesthesia under the supervision of an anaesthesiologist if available, or more commonly, an MDGP (Medical Doctor of General Practice and Emergency Medicine, or a family physician). In 2011, the training programme was upgraded from a 6-month course to 12 months under the authority of the National Academy of Medical Sciences, certified by the National Health Training Center, and currently in the process of being registered by the National Health Professional Council. This 12-month course is a combination of classroom, simulation and

clinical teaching with clinical exposure training primarily taught by anaesthesiologists.

AAs are the cadre most likely to be at a peripheral hospital in rural Nepal.⁵ In 2004, AAs were found to be providing anaesthesia for a large number of operations, with 71% providing all forms of anaesthesia.¹¹ At a 160-bed mission hospital, AAs were reportedly conducting anaesthesia for 8000 operations annually.¹¹ Further, although Nepal's rural specialist SAO density was only 0.4 per 100 000, the density of non-specialist SAOs led by MDGPs and supported by AAs was found to be eight times higher, at 3.1 per 100 000, and was associated with a twofold increase in Caesarean sections (CS).^{5 7}

Understanding how the introduction of AAs affects the volume and availability of major surgical procedures is critical for assessing the effectiveness of NPAP initiatives. The findings from this study will inform the MoHP's National Surgical, Obstetric and Anesthesia Plan. Beyond implications for Nepal, the quantified impact of NPAPs will provide evidence for policymakers addressing surgical workforce shortages in low-resource settings. This study assesses the deployment of AAs in primary and secondary government hospitals in Nepal during 2008/2009 to 2023/2024 on hospitals' capacity to perform any major surgery, and on the volume performed.

METHODS

Quantitative methods

Data collection and preparation

Retrospective data from the MoHP's Health Management Information System database was retrieved for the fiscal years 2008/2009 to 2023/2024 for 107 primary and secondary A government hospitals in Nepal. Two hospitals with AAs deployed before the study period and seven in the capital city with various other factors related to surgical care were excluded, leaving 98 hospitals in the dataset. Of the 98 hospitals, 84 (85.7%) received an AA between 2008/2009 and 2023/2024 enabling a quasi-experimental, staggered difference-in-difference (DiD) analysis to assess the effects of the AA deployment by using pre-AA deployment hospital data and hospitals that never received AAs as controls.

Study variables

The primary outcomes were (1) a hospital's ability to perform any major surgery (defined by performing ≥ 1 major surgery that calendar year) and (2) the annual number of major surgeries performed. Examples of major surgeries include appendectomy, herniotomy, hysterectomy, open fracture management, orthopaedic surgeries and CSs. The main exposure variable is the year the AA was first deployed. Secondary analysis distinguished between procedure types, exploring differential effects of the intervention between CSs and non-CS major surgeries.

Population density was obtained from the national census in 2001, 2011 and 2021 by district. Human

Development Index (HDI) was pulled from the Nepal Human Development Reports, providing data for 2001 and 2011 at the district level, 2006 at the developmental region level and 2019 by province. The data for missing years was estimated by linear interpolation.

Statistical analysis

Assessing the effect of AA deployment on the availability of any major surgery

The effect of AA deployment on the availability of major surgery services was assessed by fitting a two-way fixed-effects logistic regression model leveraging the staggered rollout to isolate the causal impact of AA deployment on hospitals' ability to perform any major surgeries.¹² Confounding factors (population density and HDI), hospital characteristics (governance, hospital level and geographical region) and procedure type were included. Hospitals that never received an AA and the years before a hospital received an AA served as controls.

Assessing the effect of AA deployment on the number of major surgeries

The effect of AA deployment on the number of major surgeries performed was evaluated using the staggered DiD method developed by Callaway and Sant'Anna (2021).¹³ To isolate the impact of AAs on surgical volume, the analysis was restricted to hospitals able to perform at least one major surgery that year, using the years before hospitals received an AA as the control. A generalised linear model was developed to adjust for confounders including surgery type, hospital governance, hospital level, population density, HDI and geographical region. Residuals from this model were incorporated into the DiD model using the 'did' package in R to estimate the average treatment effect on the treated (ATT). ATT is the

DiD estimate comparing change in outcomes over time between between the treated group (post-AA hospital years) and controls pre-AA hospital years), thus isolating changes due to the impact of AA deployment from any underlying time trends common to all hospitals, allowing for causal inference.

Residual diagnostics and event-study plots were used to validate model assumptions, including the parallel trends assumption. All statistical tests were two-tailed, with a significance threshold of $p < 0.05$ with 95% CIs for all ORs.

Sensitivity analysis

To ensure the robustness of findings, the model was run using randomly assigned AA deployment years as a placebo test, demonstrating no significant effects on primary outcomes.

Qualitative methods

Qualitative data were collected from seven purposely selected hospitals and from key stakeholders at the Provincial Health Directorate and the MoHP. Hospitals were purposefully sampled to represent diverse governance structures, hospital levels, geographical regions and available staff. Staff composition included three hospitals with anaesthesiologists and other specialists (ie, surgeons or obstetricians), three with specialists only and one with other task-shifted cadres such as advanced skilled birth attendants (ASBAs) but no specialists (see figure 1 and online supplemental table S4).

Multiple interviews for qualitative data were conducted using standardised questionnaires (see online supplemental material, Combined Questionnaire). At each of the sites, one focus group discussion with the operating theatre (OT) team, key informant interviews with all AAs and in-depth interviews (IDI) with the medical

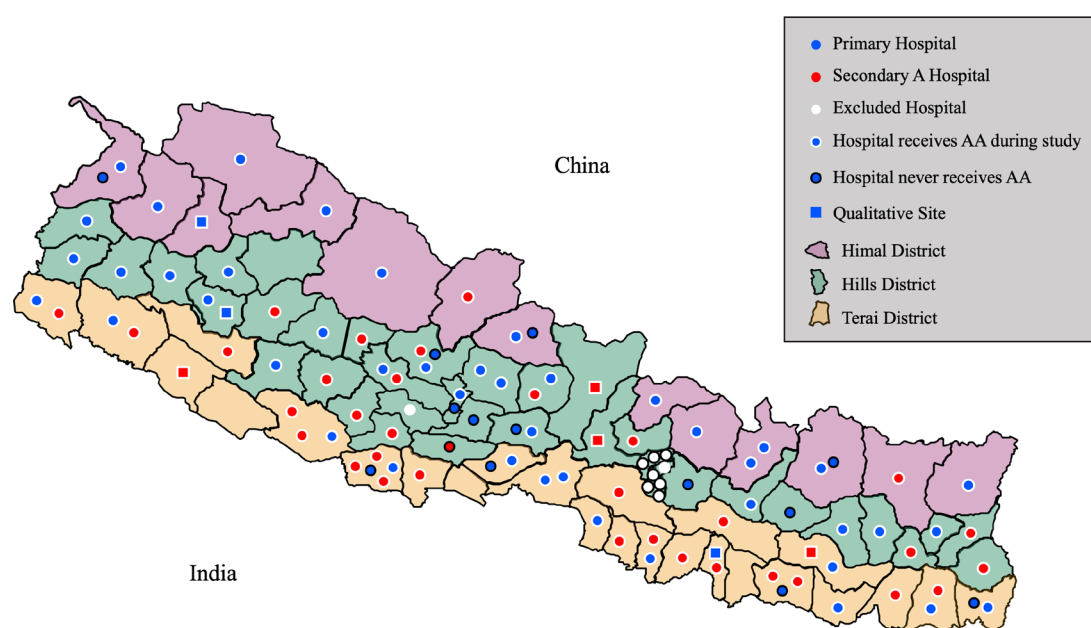


Figure 1 Map of hospital sites by district and geographical regions of Nepal (n=107). District colours show geographical regions. 98 total hospitals included in the analysis. AA, anaesthesia assistant.

superintendents and available anaesthesiologists were conducted (see online supplemental table S4). In addition, IDIs with three provincial health directors and one director from the MoHP were completed. All interviews were recorded, transcribed and translated into English.

Manuscripts were reviewed using thematic content analysis, with one research member drafting a descriptive preliminary analysis. Themes were then independently identified by team members and finalised through consensus discussions. Data were coded and analysed using ATLAS.ti software.

Quantitative and qualitative findings were triangulated to assess convergence across prespecified and emergent themes.

RESULTS

Quantitative results

Ninety-eight government hospitals were included in the analysis, with major surgical data for a total of 1205 hospital-years between 2008/2009 and 2023/2024. Hospital-years were defined as one hospital's major surgery data in a given year. Hospitals performed major surgery during 61.3% of years, with a median of 108

procedures (IQR 31–290) during years that they could perform any major surgery.

Eighty-four hospitals received an AA at some point for a median of 8 years (IQR 2–16 years) during the study period (figure 1), providing 651 pre-AA hospital-years and 330 post-AA hospital-years. Fourteen hospitals never received an AA (224 hospital-years). Before AA deployment, hospitals performed major surgeries 35.8% of the years, completing a median of 0 (IQR 0–14) procedures each year. When surgeries took place before AAs were deployed, MDGP doctors would typically provide both the spinal anaesthesia and perform the CS. After AA deployment, hospitals performed major surgeries 94.5% of years, completing a median of 123 (IQR 37–334) procedures annually. Notably, four primary, locally governed hospitals that received an AA conducted no procedures due to a non-functional OT.

Table 1 presents baseline facility characteristics and surgical outcomes for each hospital-year, stratified by AA deployment status. For detailed, wave-by-wave descriptives, see online supplemental table S1. Event studies showing major surgery numbers and proportion of hospitals performing any major surgery by both calendar year

Table 1 Hospital characteristics and outcomes by AA deployment status (hospital-years)

	No-AA ever, n (%)	Pre-AA, n (%)	Post-AA, n (%)	Raw difference (post – pre)
N (hospital-years)	224 (18.6)	651 (54.0)	330 (27.4)	–
Panel A: hospital characteristics				
Hospital level				
Primary	208 (92.9)	199 (60.3)	334 (51.3)	–
Secondary	16 (7.1)	131 (39.7)	317 (48.7)	
Governance				
Local	160 (71.4)	74 (22.4)	91 (14.0)	–
Provincial	64 (28.6)	256 (77.6)	560 (86.0)	
Geography				
Hills	112 (50.0)	129 (39.1)	266 (40.9)	–
Himal	64 (28.6)	116 (35.2)	252 (38.7)	
Terai	48 (21.4)	85 (25.8)	133 (20.4)	
Population density (people/km ²)	230.2±172.9	201.7±181.9	237.9±208.5	+36.2
HDI (%)	54.1±5.1	50.2±6.2	55.5±5.6	+5.3
Panel B: outcomes				
Hospital able to provide any major surgery				
% hospital-years with ≥1 major surgeries	2.7	35.8	94.5	+58.7
% hospital-years with ≥1 CSs	1.3	32.7	93.1	+60.4
% hospital-years ≥1 non-CS major surgeries	1.8	22.7	85.1	+62.4
Volume of major surgeries provided				
Median major surgeries (IQR)	0 (0–0)	0 (0–14)	123 (37–334)	+123
N shows the number of hospital-year observations, defined as one hospital's surgical data for a given year. Hospitals change treatment groups over time based on when they receive an AA. Categorical variables shown as n (%). Raw difference=postAA – pre-AA in % points for proportions or absolute cases for counts.				
AA, anaesthesia assistant; CS, Caesarean section; HDI, Human Development Index.				

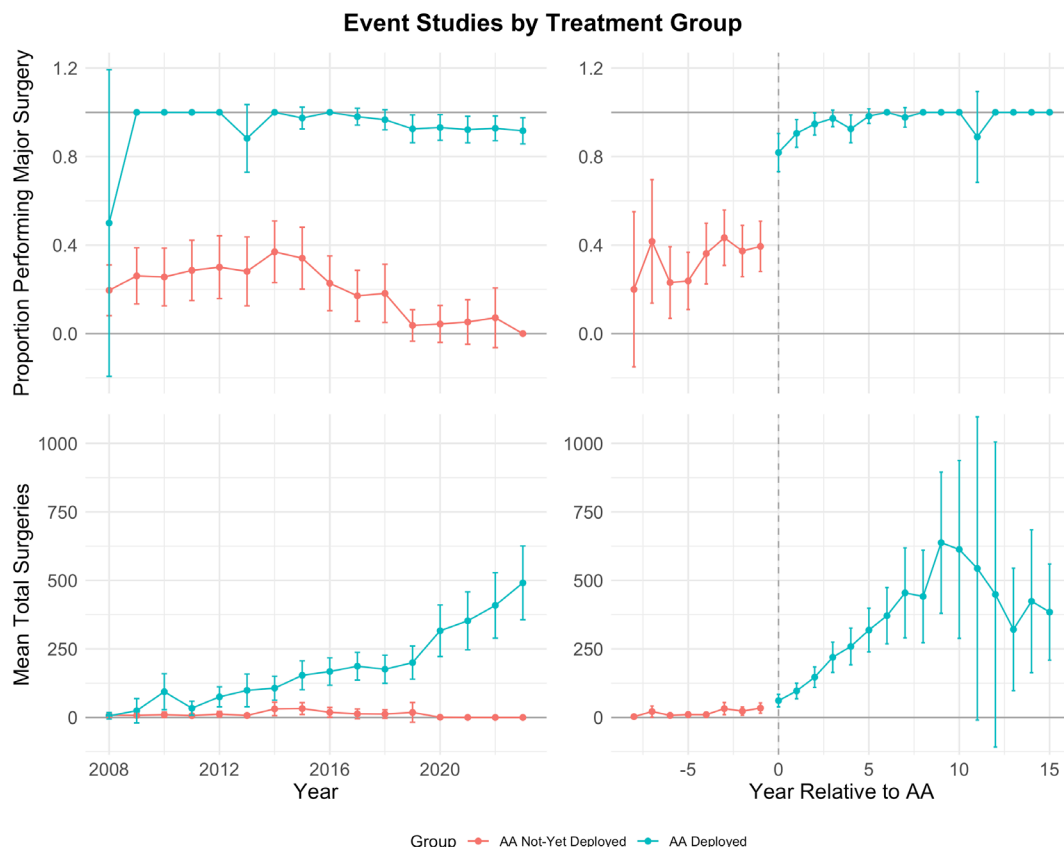


Figure 2 Event studies by calendar year and year relative to AA deployment before and after AA deployment (n=84) for total number of major surgeries and proportion of hospitals performing any major surgeries. AA, anaesthesia assistant,

and year relative to the deployment of AAs are presented in figure 2. Treatment status and data availability by hospital and year are shown in online supplemental figure S1.

Hospitals providing any major surgery: binary two-way fixed effects analysis

In an unadjusted model, the odds of a hospital performing any major surgery during post-AA years was 59.2 times that during pre-AA years (crude OR=59.2, 95% CI 40.6 to 88.8). Adjusting for covariates, hospitals had 45.4 greater odds of performing major surgery post-AA years compared with pre-AA years (adjusted OR (aOR)=45.40, 95% CI 23.48 to 92.15, $p<0.001$). Moreover, the odds of performing major surgeries increased over time post-deployment (aOR=1.50, 95% CI 1.22 to 1.89, $p<0.001$), suggesting that hospitals progressively overcame barriers to provide major surgery.

Governance emerged as a critical determinant, with provincially governed hospitals 6.5 times more likely to perform surgeries than locally governed hospitals (aOR=6.49, 95% CI 3.59 to 12.07, $p<0.001$). Increased population density showed a slight decrease in the odds of providing major surgery (aOR=0.998, $p=0.042$). Geographical region, the calendar year, HDI and hospital level were not significant predictors (see table 2).

Procedure type

Before AA deployment, hospitals performed CSs 32.7% of years, rising to 93.1% of years after AA deployment. Similarly, hospitals performed non-CS major surgery 22.7% of years, rising to 85.1% of years after AA deployment. AAs were particularly instrumental in increasing access to CS, with hospitals being 50 times more likely to provide CSs post-deployment (aOR=49.82, 95% CI 26.01 to 99.96, $p<0.001$). In contrast, the odds of non-CS major surgeries were lower, though substantial (aOR=14.75, 95% CI 8.79 to 25.23, $p<0.001$). Comparatively, AAs were 3.4 times more likely to increase access to CS than they were to non-CS major surgeries (aOR=3.46; 95% CI 3.03 to 4.07); $p<0.001$). Analysis by procedure type can be seen in online supplemental table S2.

Hospitals major surgery volume: staggered difference-in-difference analysis

Eighty hospitals that received AAs were able to perform any major surgery totalling 733 hospital-years, which were included in this analysis. Of these, 118 hospital-years were before AA deployment, functioning as the control, and 615 hospital-years post-AA deployment. The unadjusted estimates of the ATT were 99.01 (95% CI 41.33 to 156.68). Controlling for covariates, there was a positive and statistically significant ATT of 99.94 (95% CI 45.90 to 153.98).

Table 2 Crude and adjusted ORs for major surgery availability following AA deployment (n=98)

Variable	Univariate analysis		Multivariate analysis		
	cOR (95% CI)	P value	aOR (95% CI)	P value	
Intercept	1.59 (1.46 to 1.72)	<0.001	0.12 (0.01 to 0.97)	0.048	
AA deployed	59.24 (45.22 to 78.65)	<0.001	45.40 (23.48 to 92.15)	<0.001	
Time relative to AA deployment (years)	1.54 (1.48 to 1.60)	<0.001	0.91 (0.81 to 1.02)	0.114	
Dummy year	1.17 (1.15 to 1.20)	<0.001	0.98 (0.92 to 1.06)	0.659	
Governance	Local	Reference			
	Provincial	9.56 (7.77 to 11.82)	<0.001	6.49 (3.59 to 12.07)	<0.001
Hospital level	Primary	Reference			
	Secondary A	3.75 (3.11 to 4.54)	0.066	1.62 (0.97 to 2.72)	0.066
Geography	Hills	Reference			
	Terai	0.99 (0.77 to 1.26)	0.908	1.31 (0.70 to 2.45)	0.397
	Himal	1.23 (0.92 to 1.63)	0.160	1.41 (0.82 to 2.42)	0.213
HDI (%)	1.06 (1.04 to 1.07)	<0.001	0.99 (0.95 to 1.03)	0.606	
Population density	1.00 (1.00 to 1.00)	0.138	1.00 (1.00 to 1.00)	0.042	
Interaction terms					
AA deployed:time relative to AA	3.57 (3.10 to 4.16)	<0.001	1.50 (1.22 to 1.89)	<0.001	

Bolded values represent significant p-values <0.05.
AA, anaesthesia assistant; aOR, adjusted OR; cOR, crude OR; HDI, Human Development Index.

This translates to an additional 100 major surgeries each year after a hospital received an AA, compared with the years a hospital performed any major surgery before an AA was deployed, shown in online supplemental table S2. See the number of major surgeries before and after AA deployment among hospitals able to perform any major surgery over time and by procedure type in online supplemental figure S2.

The event study analysis further supported the significance of the findings, analysing the dynamic effects of the intervention over time in online supplemental table S3. The overall dynamic ATT was estimated at 127.39 (95% CI 65.54 to 189.24). The slightly higher dynamic ATT suggests that the intervention becomes more effective over time. However, the isolated significant finding in the pretreatment and post-treatment periods due to small treatment groups between 2008/2009 and 2023/2024 and the overall imprecision in the estimates suggests caution.

Qualitative analysis

The qualitative results explore key themes related to AA's contributions, including their importance in enabling surgical care, their specific roles in rural and larger hospitals and the evolution of surgical services before and after their deployment. Online supplemental table S4 summarises the characteristics of hospitals and interview types included in the qualitative analysis.

Importance of anaesthesia assistants

Interviews consistently highlighted how AAs saved lives and prevented costly patient referrals that

disproportionately affected the poor. In larger hospitals, AAs enabled surgeries to be conducted simultaneously. They were recognised as vital team members, significantly contributing to the functionality of surgical teams and the healthcare system. Hospital directors and senior professionals recognised the impact AAs had on healthcare delivery.

“AAs are the backbone of the hospital.” ... “they are technically sound.” - medical superintendent, secondary A hospital

Before the deployment of anaesthesia assistants

The state of surgical services before the deployment of AAs was often poor, marked by limited services and a lack of skilled HRs. Many hospitals struggled to provide even basic surgical services with the financial burden often falling on the poor and most disadvantaged.

There was no conduction of such surgeries here before my arrival. After 6 months, we started appendectomies, orthopedic surgeries, and gradually we extended the services.
- AA, secondary A hospital

After the deployment of anaesthesia assistants

In more rural hospitals, AAs made surgery possible. In large, urban hospitals, AAs provided essential support allowing for surgeries to be conducted simultaneously while ensuring continuous patient care even when anaesthesiologists were unavailable. However, the extent of these services varied significantly depending on the availability of resources and trained personnel.

AA's are very important and play a vital role in the team. In my case, we both do our job well and know our limitations. Having an AA by your side makes work easier. We divide our shifts as well. One of us is always available for patients.
- anaesthesiologist, secondary A hospital

Referrals

Interviews repeatedly emphasised AAs' role in reducing the need for referrals, particularly in rural hospitals. Their ability to stabilise patients and provide critical care made them indispensable, especially in areas with limited higher-level medical services. However, despite the crucial role of AAs, referrals still occurred due to the lack of equipment, such as general anaesthesia machines, CT scans and intensive care unit (ICU) setups.

Definitely the referral rate has decreased due to the availability of surgical services. Delivery cases are managed here, orthopedic cases are also managed here. Some cases need referral we can stabilize and refer to the higher center.
- AA, one of the most remote hospitals

While [an] AA was absent and [the] Gynecologist was present in the hospital, we had to refer out three probable CS cases. The patient had to spend a lot of money, and I know that it was very difficult to manage money for them. If [an] AA was available here in the hospital, the poor people would not have to spend a lot of money. I feel so sad facing these types of situations.
- healthcare worker

Due to the lack of GA machines, we have been referring out cases requiring GA machines, ICU, NICU.
- AA, primary hospital

Future direction

There is a consensus that strategic support from provincial and federal governments is needed to enhance surgical services in peripheral hospitals. This includes policy implementation, infrastructure development and ensuring the availability of skilled HRs. Although the federal MoHP proposed the organisational structure for primary and secondary hospitals, there is inadequate financial security to implement and sustain these structures.

To strengthen the emergency surgery in peripheral hospitals, the production of MDGPs [family physicians] and AAs should be increased, and its quality should also be improved. One MDGP and one AA cannot provide 24 hours service in the hospital; we need to come out of this. The Federal government should take responsibility for the key human resources of the hospital. It would be better if the federal government would implement the [Organisation and Management Survey] with financial responsibility.
- a provincial director

Surgery is itself a complex thing, it should not be taken lightly. In addition to that, referral mechanisms should be strengthened from Primary Level to Tertiary Level.
- a provincial director

Triangulation

Quantitative and qualitative results were triangulated across themes and described in [table 3](#). The majority of themes converged, with strong qualitative and quantitative evidence for the improvement of surgical access after the deployment of AAs. Equity was a major theme in the qualitative interviews, but was not apparent in the quantitative data.

DISCUSSION

Task-shifting addresses shortages of specialist anaesthesia providers in both high- and low-resource settings.⁶ Studies have shown that NPAPs provide the majority of anaesthesia care in low-resource settings, sometimes without formal training pathways.^{5 8–10 14 15}

We found that after Nepali government hospitals received an AA, they were 45.4 times more likely to be performing any major surgery (aOR=45.40; 95% CI 23.48 to 92.15). In addition, the proportion of hospitals performing major surgeries rose from 36% to 95% of hospital-years after AA deployment. Interviewees frequently cited the positive impact of AAs on surgical access. Further, after AA deployment, hospitals were 3.46 times more likely to perform CSs compared with non-CS major surgeries (aOR=3.46; 95% CI 3.03 to 4.07; $p<0.001$). The difference may be due to broader policies targeting maternal health, such as the ASBA initiative that trains medical officers (MOs) to perform CSs and the Safe Motherhood Programme.¹⁶ Further, district hospitals are often staffed with MDGP doctors, who are most proficient in CS and may be less comfortable with other major surgeries.

Despite the effect of AA deployment increasing access to major surgery, there were other limiting factors. Although four health facilities received an AA, they were not able to perform major surgery due to a non-functional OT. This is frequently cited in the literature.^{5 17 18} In a cross-sectional study spanning three continents, 42.9% of facilities were unable to provide CSs because of non-functioning equipment.¹⁹ In Nepal, 46% of hospitals in remote districts had an adequate surgical environment and only 28% possessed functional anaesthesia machines.⁵ As one interviewee said, "Due to the lack of GA machines, we have been referring out cases...", despite adequate HR. Our study reiterates the need for parallel investments in infrastructure and equipment maintenance for expanded surgical access and successful task-shifting.

Before AA deployment, hospitals performed a median of 0 (0–14) major surgeries each year. After deployment, this increased to 123 (37–334) major surgeries each year. The DiD analysis quantified the effect of AA deployment to an additional 100 major surgeries per hospital per year (ATT=99.94, 95% CI 45.90 to 153.98). These results are consistent with another study, which found that every additional perioperative provider (including NPAPs) resulted in an additional 110 annual cases.²⁰ Another

Table 3 Triangulation of quantitative and qualitative results across key emergent themes

Theme	Quantitative evidence	Qualitative evidence	Convergence
Surgical access	Post-AA deployment, hospitals were 45 times more likely to perform any major surgery (aOR 45.40, 95% CI 23.48 to 92.15) with increased odds over time.	Interviews from all cadres frequently cited how AAs 'made surgery possible' and 'saved lives', especially in rural areas. 'After I joined, we performed CS, general surgery, ... and orthopedic surgeries.'	Strong convergence
Surgical volume	After AAs were deployed, hospitals performed an additional 100 major surgeries each year. (ATT=99.94, 95% CI 45.90 to 153.98), with some evidence of increase over time.	Hospitals described an initial learning curve followed by expanding services as teams integrated AAs into workflows. 'After 6 months ... gradually we extended services'. Higher-level hospitals mentioned better provision of services.	Convergence
Caesarean sections	AAs were 3.46 times more likely to increase CS than non-CS major surgeries. (CS aOR=49.82; 95% CI 26.01 to 99.96, vs non-CS aOR 14.75 95% CI 8.79 to 25.23).	Interviewees frequently cited CS delivery ('delivery cases are managed here'), and one example cited that without an AA, a hospital 'referred out three probable CS cases'.	Strong convergence
Equity	Increased population density slightly decreased the odds of major surgery provision after AA deployment (p=0.042). Thus, the more rural, the more likely AA deployment increased surgical access. HDI and geographical regions were insignificant.	Service equity emerged as a motivating factor for AAs, who cited that their work meant that 'poor people would not have to spend a lot of money' to travel for services, and increasing access to rural and underserved areas.	Partial divergence
Barriers	Four locally governed primary hospitals never performed major surgery; some hospitals had to stop performing major surgery.	Staff noted ongoing referrals due to lack of machines, ICU/NICU and funding gaps, emphasising that human resources alone cannot fix all infrastructural shortcomings.	Convergence
Governance	Provincially governed hospitals were 6.5 times more likely to perform surgeries (aOR=6.49, 95% CI 3.59 to 12.07, p<0.001).	Directors stated that 'local governments are trying, but they struggle'. Discussions focused on financing and policy ('federal government should implement').	Partial convergence

AA, anaesthesia assistant; aOR, adjusted OR; ATT, average treatment effect on the treated; CS, Caesarean section; HDI, Human Development Index; ICU, intensive care unit; NICU, neonatal ICU.

study found that nurse anaesthetists were associated with an increased volume of surgical cases in rural Kenya, concluding that they may be filling a void in surgical care, but the volume was not quantified.⁸

When triangulating across quantitative and qualitative findings, a coherent narrative emerges. The strongest convergence was observed for surgical access, volume and caesarean delivery, with effect sizes mirroring clinicians' accounts that AAs made surgery possible in previously non-functional settings. Respondents' consistent descriptions across facilities suggest that the impact of AAs is structural rather than idiosyncratic, functioning as a catalytic input that allows existing surgical capacity, staff and infrastructure to be used effectively. A divergent finding in the qualitative data was the motivation for their work, with AAs repeatedly referencing the disproportionate impact of surgical access on poor community members, 'If [an] AA was available here in the hospital, the poor people would not have to spend a lot of money'. Together, these findings position AA deployment as a powerful but structurally contingent strategy for national surgical scale-up.

Our study did not evaluate patient outcomes, so no conclusions about the quality of care should be drawn,

but existing evidence can be considered. In 2014, 14 AAs in rural Nepal logged a total of 4143 cases with a 6% anaesthesia complication rate, comparable to tertiary hospitals in Nepal and India, but relative risk should be considered.²¹⁻²³ A 2014 Cochrane review concluded no definitive statement could be made about the quality between anaesthesia providers given potential for confounding and lack of randomisation.²⁴ More recently, in 2024, a non-inferiority randomised controlled clinical trial in rural India saw that spinal anaesthesia failure rates provided by trained MOs were non-inferior to those provided by anaesthesiologists in low-risk surgical patients.²⁵ The authors concluded that the results may support task-sharing policies to expand anaesthesia care capacity in rural Indian hospitals.²⁵ In contrast, one meta-analysis showed increased maternal mortality when CSs were managed by NPAPs.²⁶ However, nearly three-quarters of the studies were in urban settings and 86% were in sub-Saharan Africa with vast cultural, regional and structural differences to South Asia.²⁶ Thus, while our study supports the significant impact on major surgical access and capacity, other evidence suggests that these surgical services provided may be safe, but more research is needed.

Limitations

This study did not evaluate patient outcomes, and therefore, no conclusions about the quality or safety of AA-provided care should be drawn. Second, while AAs appear to increase surgical access, the analysis could not fully account for contextual factors such as equipment availability or presence of a supervisor. Third, information was limited to the year of AA deployment, but not the length of their stay. However, once an AA was deployed, there should be a post for their position that would be filled if they left. Lastly, the staggered DiD design over a 15-year period means that each year had relatively few hospitals that received an AA that year. With fewer treatment groups per time period, there was a reduced statistical power.

CONCLUSION

This study suggests that AAs improve a hospital's ability to perform major surgery, specifically CSs, while decreasing patient referrals and increasing surgical capacity in Nepal. Hospitals were 45 times more likely to perform any major surgery and performed an additional 100 major surgeries each year after an AA was deployed. These results underscore the role of NPAPs in improving surgical access in resource-limited settings, like Nepal, alongside other policies to create an enabling environment for surgical services.

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Contributors JP conceptualised the study, completed the initial literature review and collected primary quantitative and qualitative data. The study design, data cleaning, statistical analysis, data interpretation and further literature review was done by AKn with technical support from JS and RR. JP analysed and interpreted the qualitative data with technical support from RR, RB and AKn. AKn triangulated results. AKn drafted the manuscript and revised it with JP, RB, JS, PP, KS, AA, AKa, RRS, YA, BSC and RR. All authors reviewed and approved the final version of the manuscript. RR is the guarantor. To assist with technical coding in R (2023.12.1+402), AI (ChatGPT4.0) was used for some parts of data cleaning and production of graphs. Example prompts included: Write code to make a plot in R using the ggplot2 package, putting total_cs on the y-axis, and year_relative_aa on the x-axis from the final_data dataset. Colour the points based on the binary variable treated, and show a vertical, dashed grey line at year_relative_aa == 0. All code was thoroughly reviewed, revised and compiled by authors with experience in R.

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Data availability statement Data are available upon reasonable request.

Hospital data, with demographic characteristics removed to prevent identification of individual hospitals, will be made available upon request to the authors after approval from the Nepal Health Research Council, Nepal's Ministry of Health and Population, and the Nick Simons Institute. Qualitative data will not be made available for confidentiality purposes. This data and relevant documents will be accessible beginning with the publication of this paper. Researchers interested in conducting additional analyses are invited to submit a request. Data access will be granted to qualified investigators after review of the proposed analyses and upon signing a data access agreement that ensures adherence to ethical and confidentiality standards. Requests should be directed to the corresponding author at rajbhandari@mgh.harvard.edu. Further details regarding the access criteria and the process for data sharing will be provided upon inquiry.

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