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# Supervised anesthesiology residents do not adversely affect perioperative outcomes in elderly patient: A single-center experience from China

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## Highlights

- Medical education and robust residency training systems are fundamental pillars in developing an effective national healthcare system.
- This study demonstrates that for non-cardiac surgery in geriatric patients, postoperative morbidity and mortality rates are similar whether anesthesia is provided by a supervised final-year (CA-5) resident or an attending anesthesiologist, indicating that supervised CA-5 residents do not negatively impact patient safety.
- The current Chinese residency anesthesiology training system, when implemented with continuous supervision and rigorous national oversight, proves to be safe, ethical, and effective in patient care.

## Abstract

**Objective:** The anesthesia residency training system is designed to provide supervised practice, enabling residents to progress from simple to complex procedures and higher-risk patients. However, it remains unclear whether residents acquire sufficient competence to be considered qualified anesthesiologists by the end of their training. This study aimed to evaluate whether anesthesia care provided by supervised CA-5 residents affects postoperative outcomes in elderly patients undergoing non-cardiac surgery. **Methods:** A retrospective analysis was conducted on clinical data from elderly patients who underwent non-cardiac surgery between January 2020 and December 2021 at Songjiang Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. Patients were categorized into two groups: those managed by CA-5 residents (Resident group, n=294) and those managed by attending anesthesiologists (Attending group, n=521). Propensity score matching (PSM; 1:1) was used to ensure comparability between the groups. The primary outcome was a composite of in-hospital postoperative complications. Secondary outcomes included intraoperative hemodynamic changes, the need for intensive care unit (ICU) admission, length of ICU and hospital stays, and in-hospital mortality. Multivariable logistic regression assessed the adjusted association between anesthesia provider type and postoperative morbidity and mortality. **Results:** Among the 815

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elderly patients included, 105 (12.9%) experienced postoperative complications and 22 (2.7%) died during hospitalization. No significant differences were observed in postoperative complications or mortality between the two groups, either before PSM (morbidity: 11.9% vs. 13.4%, p=0.531; mortality: 3.7% vs. 2.1%, p=0.168) or after PSM (morbidity: 12.0% vs. 14.4%, p=0.392; mortality: 3.8% vs. 1.4%, p=0.067). Multivariate analysis confirmed that postoperative morbidity and mortality were not significantly associated with resident involvement, either before PSM (morbidity: OR=0.882, 95% CI: 0.552-1.410, p=0.600; mortality: OR=1.293, 95% CI: 0.479-3.492, p=0.612) or after PSM (morbidity: OR=0.881, 95% CI: 0.523-1.486, p=0.636; mortality: OR=3.122, 95% CI: 0.805-12.106, p=0.100). **Conclusions:** Postoperative morbidity and mortality rates in elderly patients undergoing non-cardiac surgery are comparable between those anesthetized by supervised CA-5 residents and those managed by attending anesthesiologists. These results suggest that supervised CA-5 residents do not adversely affect patient safety.

**Keywords:** Outcomes, residency, training, anesthesia education, perioperative management

## Introduction

Medical education and subsequent residency training systems are crucial for the successful development of a country's healthcare system. Internationally, medical residency training is recognized as a critical phase designed to cultivate the skills of new physicians, enabling them to practice independently. Thus, the quality of resident training directly impacts the overall standard and advancement of medical services.

However, there remains a scarcity of data regarding the quality and effectiveness of anesthesiology residency training. Over the past two decades, the development of simulation-based training models in anesthesia and perioperative management has provided opportunities for training in high-risk scenarios without compromising patient safety. These models enable educators to recreate clinical experiences that facilitate deliberate practice, evaluation, and constructive feedback for residents [1]. However, such simulation-based methods have limitations, as they cannot fully replicate the stress and unpredictability encountered in actual operating room environments.

Modern anesthesiology emphasizes enhancing perioperative quality, improving patient outcomes, and optimizing long-term prognoses. Debate continues regarding the role of anesthesia residents in influencing postoperative outcomes, raising potential ethical and economic implications for healthcare systems [2]. Anesthesia residency training programs vary significantly across countries [3]. In China, the anesthesiology residency program has undergone substantial reforms over the past few decades in response to the rapidly growing demand for high-quality perioperative care and advancements in medical science and technology [4-6]. Typically, Chinese anesthesiology residents undergo a five-year training program. In the fourth and fifth years, residents work under the supervision of attending anesthesiologists to gain extensive clinical experience, particularly in complex surgeries and the management of intermediate- to high-risk patients, thereby enhancing their perioperative management skills and overall competency [7]. Upon completion, residents become eligible to qualify as attending anesthesiologists.

To our knowledge, no studies have evaluated whether anesthesiology residents in China have acquired the requisite competence to function as qualified attending anesthesiologists by the end of their training. This study aims to assess whether anesthesia care provided by supervised CA-5 (5th-year clinical anesthesia) residents influences postoperative outcomes in elderly patients undergoing non-cardiac surgery at a university hospital, thereby assessing the readiness of senior residents to function as competent anesthesiologists.

## Materials and methods

### *General information*

A retrospective cohort study was conducted involving 846 consecutive patients aged 80 years or older (range: 80-99) who underwent non-cardiac surgery at Songjiang Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (SJHJTUSM, Shanghai, China) between January 1, 2020, and December 31, 2021. The study aimed to compare postoperative outcomes between elderly patients anesthetized by supervised residents and those managed by attending anesthesiologists.

The study protocol was approved by the Institutional Review Board and the Clinical

Research Ethics Committee of SJHJTUSM (Approval No. 2022SQ030) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all patients or their legal guardians.

### *Clinical data collection*

Preoperative and intraoperative data were obtained from the electronic anesthesia recording system, while postoperative data were retrieved from the electronic medical record system. Inclusion criteria comprised patients aged 80 years or older who underwent non-cardiac surgery and had valid intraoperative anesthesia records. Exclusion criteria included patients with incomplete clinical data, those who received only local infiltration anesthesia administered by surgeons, those anesthetized under the supervision of CA1-4 resident anesthesiologists, those undergoing emergency surgery, those with an operative duration of less than 20 minutes, those who self-discharged postoperatively, those with intraoperative blood loss exceeding 500 ml, and those requiring reoperation due to surgical complications during the postoperative period. The primary endpoint was the incidence of postoperative morbidity in patients anesthetized by supervised residents versus attending anesthesiologists. Secondary endpoints included intraoperative hemodynamic changes, need for intensive care unit (ICU) admission, length of ICU and hospital stay, and postoperative mortality, with comparisons made between the two groups.

Clinical data collected included age, gender, body mass index (BMI), type of surgery, anesthesia technique, American Society of Anesthesiologists Physical Status (ASA) classification, comorbidities, anesthesia duration, intraoperative blood loss, hemodynamic parameters, postoperative need for ICU admission, length of ICU and hospital stay (LOS, defined as the period from admission to discharge), as well as postoperative morbidity and mortality.

Surgical procedures were categorized as follows:

1. Digestive surgeries: involving the stomach, duodenum, liver, gallbladder, common bile duct, pancreas, colon, ileum, cecum, appendix, and rectum.

2. Orthopedic surgeries.

3. Craniocerebral surgeries.

4. Other surgeries: including thyroid, breast, abdominal wall, urologic, gynecologic, thoracic, ENT (ear, nose, and throat), and ocular procedures.

Anesthesia techniques were classified as either general anesthesia (with or without nerve block) or regional block (including peripheral nerve block, spinal anesthesia, and epidural anesthesia, with or without sedation). All anesthetic procedures adhered to the Anesthesia Management Regulations of SJHJTUSM. All operations were performed by surgeons in accordance with Standard Operating Procedures at SJHJTUSM.

Discharge criteria were uniformly applied as per institutional guidelines: absence of clinical complications requiring emergency intervention, visual analog scale (VAS) score below 3 with oral analgesics, and no fever within the preceding 48 hours.

Patients were excluded from analysis for the following reasons: incomplete clinical data (n=8), local infiltration anesthesia (n=10), emergency surgery (n=6), operation time less than 20 minutes (n=3), self-discharge against medical advice (n=1), intraoperative blood loss exceeding 500 mL (n=1), and reoperation due to surgical complications during the postoperative period (n=2), as shown in **Figure 1.** Additionally, no elderly patients were anesthetized by supervised CA1-4 resident anesthesiologists at SJHJTUSM. The final cohort included 815 patients, including 294 anesthetized by supervised residents (Resident group) and 521 by attending anesthesiologists (Attending group).

### *Perioperative management*

Preoperative assessment was standardized in accordance with the protocols established by SJHJTUSM. All patients were evaluated before surgery by either supervised residents or attending anesthesiologists. Standard monitoring included electrocardiogram (ECG), pulse oximetry for oxygen saturation, and end-tidal carbon dioxide ($ETCO_2$) measurement. Noninvasive blood pressure was monitored prior to the induction of general anesthesia or regional

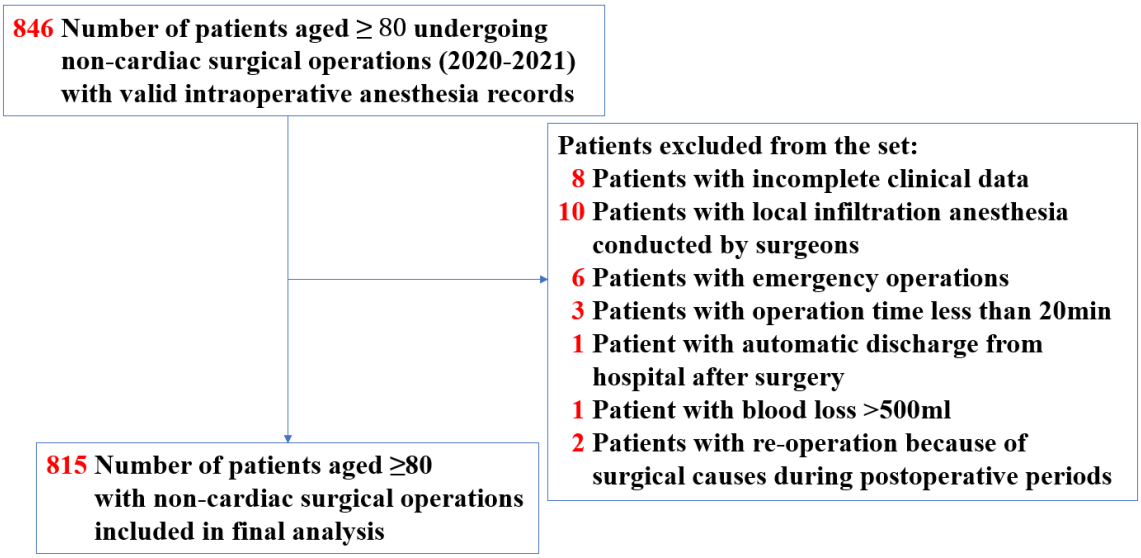


Figure 1. Patients' attrition diagram.

blockade. Invasive blood pressure and central venous pressure monitoring were employed at the discretion of the supervised residents or attending anesthesiologists. Intraoperative cardiovascular management was conducted by supervised residents or attending anesthesiologists following the Anesthesia Management Regulation of SJHJTUSM. Postoperative care was provided based on clinical judgment in accordance with the Postoperative Management Regulation at SJHJTUSM.

### *Outcomes definition*

The primary outcome was a composite of in-hospital postoperative complications requiring medical management, considered unrelated to surgical technique (e.g., excessive surgical site bleeding, reoperation, or wound infection). Postoperative complications included sepsis, pneumonia (as defined by consensus criteria), organ dysfunction (cardiac, pulmonary, gastrointestinal, renal, or hepatic), myocardial infarction, arrhythmia, central nervous system impairment (including stroke or delirium), postoperative pain, reintubation, deep vein thrombosis, non-fatal cardiac arrest, and postoperative anaphylaxis [8]. The severity of these complications was classified according to the Clavien-Dindo system [9, 10].

Secondary outcomes included intraoperative hemodynamic changes, need for ICU admission, length of ICU and hospital stay, and postoperative mortality. Given the lack of a universally accepted threshold for defining hypotension in elderly patients, we assessed baseline, maximum, and minimum values of systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR), along with the proportion and cumulative duration of intraoperative episodes with SBP<120 mmHg, SBP<90 mmHg, DBP<60 mmHg, and mean arterial pressure (MAP)<70 mmHg to reflect hemodynamic variability. Postoperative mortality was defined as all-cause death during the postoperative hospital stay.

### *Propensity score matching*

To minimize selection bias when comparing resident and attending groups, 1:1 nearest-neighbor propensity score matching was performed based on age, gender, BMI, operation type, anesthesia type, and ASA classification. This approach aimed to maximize the comparability of physiological and clinical characteristics between the groups. A matching tolerance of 0.01 was applied.

### *Statistical analysis*

Statistical analyses were performed using SPSS software (version 26.0). Normally distributed continuous variables were presented as mean ± standard deviation (SD), while non-normally distributed variables were summarized as median and interquartile range. Comparisons of continuous variables between resident and attending groups were conducted using the Student's

**Table 1. Comparison of patient information between the two groups before and after matching**

| | Before Matching | | | After Matching | | |
|---|---|---|---|---|---|---|
| | Resident (n=294) | Attending (n=521) | *P*-value | Resident (n=292) | Attending (n=292) | *P*-value |
| Age (years) | 84.06±3.27 | 84.51±3.66 | 0.078 | 84.09±3.26 | 84.12±3.46 | 0.912 |
| Sex (male) | 136 (46.3) | 211 (40.5) | 0.110 | 134 (45.9) | 129 (44.2) | 0.678 |
| BMI (kg/m$^2$) | 21.65±2.73 | 21.95±2.69 | 0.120 | 21.66±2.72 | 21.61±2.72 | 0.820 |
| Operation type | | | 0.010 | | | 0.373 |
| Digestive surgeries | 112 (38.1) | 168 (32.2) | | 110 (37.7) | 99 (33.9) | |
| Orthopedic surgeries | 92 (31.3) | 224 (43.0) | | 92 (31.5) | 109 (37.3) | |
| Craniocerebral surgeries | 6 (2.0) | 12 (2.3) | | 6 (2.1) | 9 (3.1) | |
| Others | 84 (28.6) | 117 (22.5) | | 84 (28.8) | 75 (25.7) | |
| Anesthesia type | | | 0.106 | | | 1.000 |
| General anesthesia | 178 (60.5) | 258 (54.7) | | 176 (60.3) | 176 (60.3) | |
| Regional block | 116 (39.5) | 236 (45.3) | | 116 (39.7) | 116 (39.7) | |
| ASA classification | | | 0.218 | | | 0.735 |
| 2 | 160 (54.4) | 306 (58.7) | | 160 (54.8) | 153 (52.4) | |
| 3 | 115 (39.1) | 194 (37.2) | | 114 (39.0) | 123 (42.1) | |
| 4 | 19 (6.5) | 21 (4.0) | | 18 (6.2) | 16 (5.5) | |

Note: BMI, body mass index.

t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Categorical variables were compared using the $\chi^2$ test or Fisher's exact test, as appropriate.

Univariate logistic regression was used to assess the unadjusted association between anesthesiologist level (resident vs. attending) and postoperative morbidity and mortality. Variables with a p-value <0.1 in the univariate analysis were included in a multivariate logistic regression model, adjusted for potential preoperative and intraoperative confounders. Results were reported as odds ratios (OR) with corresponding 95% confidence intervals (CI). A two-sided p-value <0.05 was considered statistically significant.

## Results

### *Results of propensity score matching (PSM)*

A total of 815 patients aged 80 years or older who underwent non-cardiac surgery were included in the final analysis. Among them, 294 patients were assigned to the resident group (136 males, 46.3%) and 521 to the attending group (211 males, 40.5%). After PSM, 292 well-balanced patient pairs were generated. The baseline characteristics of the patients, including age, gender, BMI, operation type, anesthesia type, and ASA grade, both before and after matching, are presented in **Table 1**.

### *Preoperative comorbidity and postoperative complications and mortality*

**Table 2** presents the preoperative comorbidities for both the resident and attending groups, both before and after PSM. The prevalence of hypertension was significantly lower in the resident group compared to the attending group, both before (54.1% vs. 63.0%, p=0.013) and after matching (54.1% vs. 63.4%, p=0.023). No significant differences were observed between the two groups in the following comorbidities, either before or after propensity score matching: diabetes, coronary artery disease, heart dysfunction, stroke, pulmonary hypertension, lung dysfunction, renal dysfunction, hepatic dysfunction, anemia, dementia, and arrhythmia.

Among the 815 elderly patients, 105 (12.9%) experienced postoperative complications, including sepsis (7 patients), pneumonia (31), organ dysfunction (28), myocardial infarction (5), arrhythmia (8), central nervous system impairment (20), postoperative pain (1), reintubation (1), deep vein thrombosis (2), non-fatal cardiac arrest (1), and postoperative anaphylaxis (1). Postoperative all-cause mortality occurred in 22 patients (2.7%).

**Table 2. Comparison of preoperative comorbidity between the two groups before and after matching (n, %)**

| Comorbidity | Before Matching | | | After Matching | | |
|---|---|---|---|---|---|---|
| | Resident (n=294) | Attending (n=521) | *P*-value | Resident (n=292) | Attending (n=292) | *P*-value |
| Hypertension | 159 (54.1) | 328 (63.0) | 0.013 | 158 (54.1) | 185 (63.4) | 0.023 |
| Diabetes | 44 (15.0) | 75 (14.4) | 0.825 | 44 (15.1) | 44 (15.1) | 1.000 |
| Coronary artery disease | 20 (6.8) | 45 (8.6) | 0.353 | 20 (6.8) | 28 (9.6) | 0.228 |
| Heart dysfunction | 6 (2.0) | 14 (2.7) | 0.567 | 5 (1.7) | 10 (3.4) | 0.191 |
| Stroke | 37 (12.6) | 65 (12.5) | 0.964 | 36 (12.3) | 41 (14.0) | 0.541 |
| Pulmonary hypertension | 3 (1.0) | 7 (1.3) | 0.687 | 3 (1.0) | 4 (1.4) | 1.000 |
| Lung dysfunction | 13 (4.4) | 35 (6.7) | 0.181 | 13 (4.5) | 23 (7.9) | 0.085 |
| Renal dysfunction | 8 (2.7) | 15 (2.9) | 0.896 | 8 (2.7) | 8 (2.7) | 1.000 |
| Hepatic dysfunction | 1 (0.3) | 3 (0.6) | 0.644 | 1 (0.3) | 1 (0.3) | 1.000 |
| Anemia | 4 (1.4) | 11 (2.1) | 0.444 | 4 (1.4) | 5 (1.7) | 0.737 |
| Dementia | 6 (2.0) | 12 (2.3) | 0.807 | 6 (2.1) | 8 (2.7) | 0.588 |
| Arrythmia | 19 (6.5) | 47 (9.0) | 0.199 | 19 (6.5) | 30 (10.3) | 0.101 |
| Total | 215 (73.2) | 402 (77.2) | 0.198 | 212 (72.6) | 222 (76.0) | 0.344 |

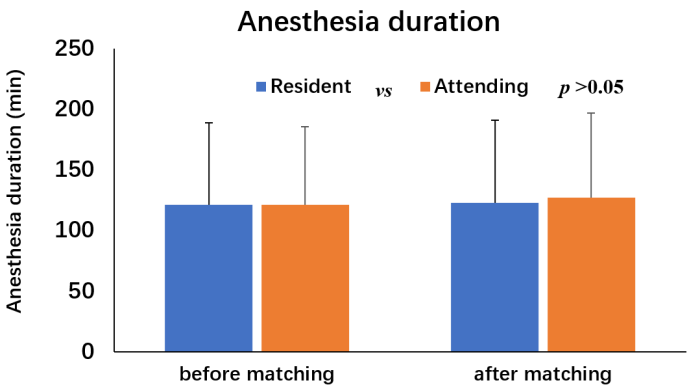


**Figure 2. Comparison of anesthesia duration between resident and attending groups.** n=294 in Resident group, n=521 in Attending group before matching. n=292 in both groups after matching.

### *Intraoperative information and hemodynamic management*

No significant difference in anesthesia duration was observed between the two groups, either before or after matching (**Figure 2**). Hemodynamic changes during surgery are presented in **Figure 3**. Intraoperative blood loss was comparable between the two groups both before [50 (20, 100) vs. 50 (20, 100), p=0.673] and after [50 (20, 100) vs. 50 (20, 100), p=0.853] PSM.

Additionally, no significant differences were found in baseline, maximum, or minimum HR, SBP, or DBP. Similarly, there were no significant differences in the proportion of patients experiencing—or in the cumulative duration of—SBP<120 mmHg, SBP<90 mmHg, DBP<60 mmHg, or MAP<70 mmHg during surgery, either before or after PSM (all p>0.05).

### *Postoperative outcomes*

Postoperative outcomes are presented in **Figure 4** and **Table 3**. No significant differences were observed between the two groups in the rate of ICU admission, length of ICU stay, or hospital length of stay, either before or after PSM (all p>0.05). Similarly, there were no significant differences in postoperative complications or mortality between the two groups, either before (morbidity: 11.9% [35/294] vs. 13.4% [70/521], p=0.531; mortality: 3.7% [11/294] vs. 2.1% [11/521], p=0.168) or after PSM (morbidity: 12.0% [35/292] vs. 14.4% [42/292], p=0.392; mortality: 3.8% [11/292] vs. 1.4% [4/292], p=0.067).

### *Postoperative morbidity and mortality: univariate and multivariate analysis*

Univariable logistic regression analysis indicated that the involvement of a resident was not a significant risk factor for postoperative morbidity [before PSM: OR=0.871, 95% CI 0.564-1.343; after PSM: OR=0.811, 95% CI 0.501-1.312] or mortality [before PSM: OR=1.802, 95% CI 0.772-4.209; after PSM OR=2.819, 95% CI 0.887-8.956].

Variables, including anesthesiologist level (resident or attending) and pre- and intra-operative

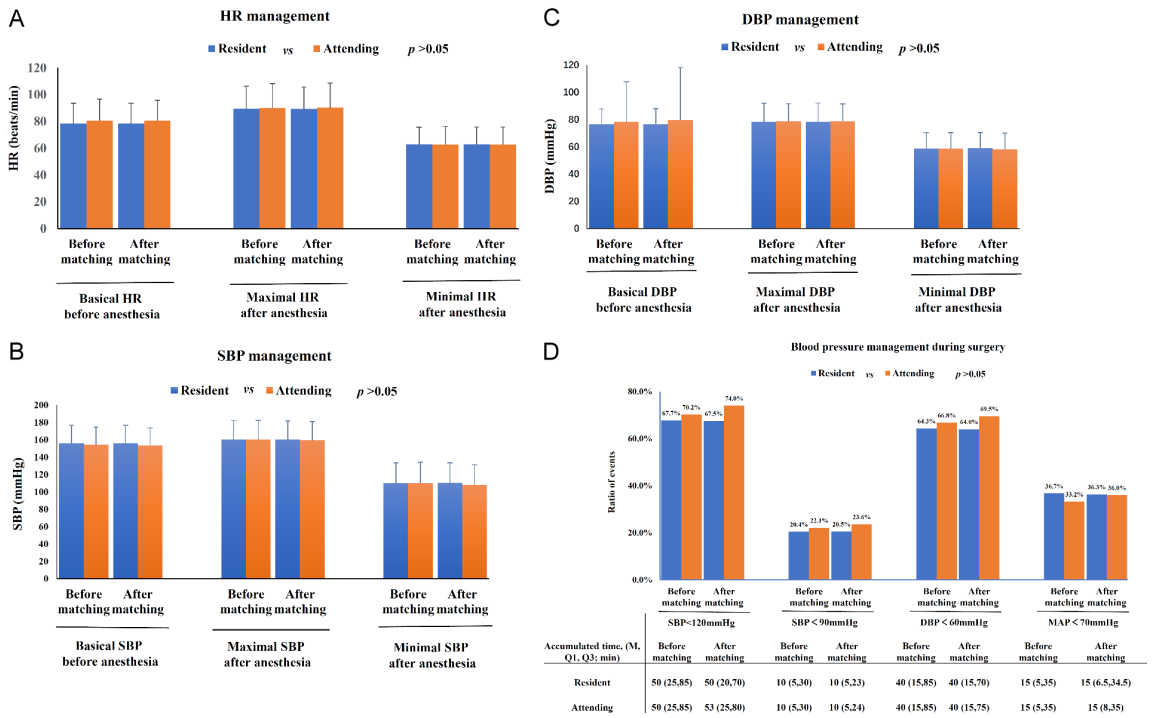


**Figure 3. Comparison of hemodynamic management during surgery between resident and attending groups.** (A) HR; (B) SBP; (C) DBP; (D) Accumulative events of SBP<120 mmHg, SBP<90 mmHg, DBP<60 mmHg, MAP<70 mmHg. n=294 in Resident group, n=521 in Attending group before matching. n=292 in both groups after matching.

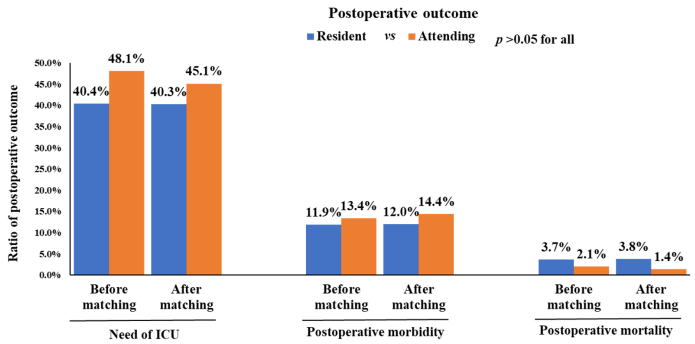


**Figure 4. Postoperative outcome after surgery between resident and attending groups.** n=294 in Resident group, n=521 in Attending group before matching. n=292 in both groups after matching.

factors with a p-value <0.1 in the univariate analysis, were incorporated into a multivariate logistic regression model to identify risk factors for postoperative morbidity. The same approach was applied for postoperative mortality. Multivariate analysis revealed that postoperative morbidity and mortality were not significantly associated with resident involvement, either before or after PSM (**Table 4**).

## Discussion

Elderly patients typically require a higher level of perioperative care compared to younger patients. This study aimed to evaluate whether the involvement of supervised CA-5 anesthesiology residents affects postoperative outcomes in elderly patients undergoing non-cardiac surgery. The results indicated that the involvement of supervised CA-5 residents did not negatively impact patient safety. Specifically, no significant differences were found in postoperative morbidity or mortality between cases managed by supervised residents and those handled by attending anesthesiologists. Additionally, comparable outcomes were observed in intraoperative hemodynamic stability, need for ICU admission, length of ICU stay, and total hospital stay. These findings suggest that the current residency training system is effective and does not increase perioperative risk in patients aged 80 years or older undergoing non-cardiac surgery.

Perioperative quality and safety are major concerns in modern healthcare systems and are closely linked to long-term patient survival [11]. In this study, we compared the performance of 5-year residency-trained anesthesiologists with that of attending anesthesiologists in managing

**Table 3. Comparison of the length of ICU stay and hospital stay between the two groups before and after matching**

| | Before Matching | | | After Matching | | |
|---|---|---|---|---|---|---|
| | Resident (n=294) | Attending (n=521) | *P*-value | Resident (n=292) | Attending (n=292) | *P*-value |
| Length of ICU stay (days) | 1 (1, 2)[a] | 1 (1, 2)[b] | 0.504 | 1 (1, 2)[c] | 1 (1, 2)[d] | 0.393 |
| Length of hospital stay (days) | 11 (7, 15) | 11 (8, 17) | 0.280 | 11 (7, 15) | 11 (7, 17) | 0.285 |

Note: [a]n=118; [b]n=248; [c]n=117; [d]n=130. Date are expressed as median (M) and interquartile range (Q25, Q75).

**Table 4. Univariate and multivariate logistic analyses of risk factor for morbidity and mortality**

| | Univariable logistic analysis | | | Multivariable logistic analysis with adjustment | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value |
| Morbidity -residency *vs* attending | | | | | | |
| Before Matching | 0.871 | 0.564-1.343 | 0.531 | 0.882 | 0.552-1.410 | 0.600 |
| After Matching | 0.811 | 0.501-1.312 | 0.392 | 0.881 | 0.523-1.486 | 0.636 |
| Mortality -residency *vs* attending | | | | | | |
| Before Matching | 1.802 | 0.772-4.209 | 0.174 | 1.293 | 0.479-3.492 | 0.612 |
| After Matching | 2.819 | 0.887-8.956 | 0.079 | 3.122 | 0.805-12.106 | 0.100 |

Note: OR, odds ratios; CI, confidence intervals.

patients over 80 years of age undergoing non-cardiac surgery. Administering anesthesia to this advanced-age population presents unique challenges due to their physiological vulnerability. Our findings contribute to the ongoing discussion regarding the training of resident anesthesiologists and its impact on perioperative outcomes. They also support the practice of supervising residents by attending anesthesiologists during anesthesia delivery in elderly patients undergoing non-cardiac surgery. It is important to note that all anesthesia-related decisions and perioperative management in this study were either directly performed or closely supervised by attending anesthesiologists, in accordance with institutional policy that prohibited unsupervised procedures.

In this study, postoperative morbidity during hospitalization was comparable between the two groups (11.9% vs. 13.4%), and was relatively low compared to the 13.70% reported by Portuondo et al. in high-risk inpatients undergoing non-cardiac surgery [12]. Postoperative mortality (3.7% [11/294] in the resident group vs. 2.1% [11/521] in the attending group before PSM; 3.8% [11/292] vs. 1.4% [4/292] after PSM) was consistent with the 2.5% rate reported by Ogata et al. and did not differ significantly between groups [13]. Other studies have reported morbidity and mortality rates in elderly surgical patients ranging from 11% to 31.7% and 2% to 7%, respectively [14-16]. Thus, the morbidity and mortality observed in our study—whether in patients managed by supervised residents or attending anesthesiologists—were not higher than those previously reported.

To our knowledge, this is the first large, single-center study in China to focus specifically on an elderly surgical population. Although not statistically significant, there was a trend toward lower postoperative mortality in patients anesthetized by attending anesthesiologists compared to those managed by supervised residents (1.4% vs. 3.8%, p=0.114 after matching). Multivariate analysis confirmed that a supervised resident was not an independent risk factor for postoperative morbidity or mortality in elderly patients undergoing non-cardiac surgery.

Conversely, patients in the attending group showed a non-significant trend toward higher postoperative morbidity in our analysis. This may be attributable to selection bias, as patients in the attending group had a higher prevalence of hypertension (63.4% vs. 54.1%, p=0.023) and a tendency toward more frequent lung dysfunction (7.9% vs. 4.5%, p=0.085) compared to those in the supervised resident group. However, multivariate analysis indicated that a supervised resident was not an indepen-

dent risk factor for postoperative morbidity. Additionally, no significant differences were observed between the two groups in terms of ICU admission rates, duration of ICU stay, or overall hospital stay.

Intraoperative hypotension is common during surgery and has been increasingly associated with elevated risks of postoperative morbidity and mortality in high-risk patients [17, 18]. Interestingly, Wanner et al. found that even a 60% reduction in hypotension time (MAP<65 mmHg) did not significantly reduce the incidence of acute myocardial injury or 30-day MACE/AKI [19]. Their study also reported no significant difference in postoperative complications between groups managed with different blood pressure targets (MAP≥60 mmHg vs. ≥75 mmHg) in high-risk patients undergoing major non-cardiac surgery [19]. In our study, we compared intraoperative hemodynamic profiles between the two groups and found no significant differences in HR, SBP, DBP, extreme values, or cumulative duration of SBP<120 mmHg, DBP<90 mmHg, or MAP<70 mmHg. These results suggest that hemodynamic management by supervised resident anesthesiologists is comparable to that of attending anesthesiologists.

In our view, several factors contribute to these findings. Over the past decade, China's residency training system has increasingly emphasized core competency-based education, particularly focusing on clinical skills, with ongoing efforts to enhance training quality [5]. The Chinese government has implemented clear standards for anesthesiology residency programs, ensuring the delivery of high-quality education and comprehensive skill development. This enables residents to acquire robust clinical competencies throughout the standardized three-year training program.

Subsequently, residents undergo an additional two years of advanced training as anesthesia attendings. During this stage, they gain substantial clinical experience—particularly in managing complex operations and intermediate- to high-risk patients—under the supervision of senior anesthesiologists. This structured progression ensures that senior residents are fully prepared to independently perform complex anesthesia procedures before transitioning to attending physicians.

Moreover, with the global population aged ≥80 years growing steadily, anesthesiology residents are now presented with more opportunities to participate in the perioperative care of elderly patients, further enriching their clinical exposure and experience [20].

Several studies have investigated the role of residents in surgical procedures beyond the field of anesthesiology. Santibanes et al. reported that the involvement of supervised residents as operating surgeons in procedures of varying complexity did not adversely affect patient safety [21]. Similarly, an analysis by Lee et al. showed no significant difference in 30-day morbidity rates when residents participated in laparoscopic-assisted vaginal hysterectomy (LAVH) [22]. These findings imply that resident involvement in LAVH may be a feasible strategy to maintain educational standards without compromising patient safety.

However, many of these studies did not specify the complexity of the surgeries performed by residents. In our study, PSM was employed to balance variables including age, gender, BMI, operation type, and anesthesia type between groups involving supervised residents and attending anesthesiologists. After matching, the results remained consistent with those before matching, indicating that the supervised resident was not an independent risk factor for postoperative morbidity or mortality. Therefore, we conclude that supervised fifth-year residents can safely administer anesthesia to elderly patients undergoing non-cardiac surgery, reflecting significant advancements in the Chinese anesthesiology residency training system over the past decade.

A major limitation of this study is its retrospective design, which inherently carries the potential for selection bias, particularly with attending anesthesiologists assigning cases. This bias is difficult to quantify and presents a challenge in interpreting the results. Therefore, further investigation through prospective randomized studies is necessary to provide more definitive conclusions. Additionally, although PSM was used to balance several confounders between the two groups, we cannot rule out the possibility that more nuanced differences might emerge if similar analyses were conducted over a longer period, across more specific procedures, or with stricter stratification by surgical complexity.

## Conclusions

Our study demonstrated that the postoperative morbidity and mortality rates in elderly patients undergoing non-cardiac surgery under anesthesia administered by supervised CA-5 residents were comparable to those performed by attending anesthesiologists. These findings indicate that supervised CA-5 resident anesthesiologists do not compromise patient safety. This supports the current structure of the Chinese anesthesiology residency training system, suggesting that it is safe and ethical when implemented with continuous supervision and national oversight.

**Availability of data and material:** The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

**Author contributions:** Weixing Wang, Yanxuan Shi and Jiawen Tang helped with design of study, acquisition, analysis, interpretation of data, and manuscript drafting for intellectual content. Dehua Wu helped with the conception of study, design of study, analysis, interpretation of data, and manuscript drafting for intellectual content. Guoqing Ding helped with the conception of study, design of study, interpretation of data, and manuscript drafting for intellectual content. Tao Zhu helped with the conception of study, design of study, interpretation of data, and manuscript drafting for intellectual content.

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