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Article

Training in Emergency Coronary Artery Bypass Grafting in the UK: Early Clinical Outcomes and Surgical Practice

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Abstract

Background: Little is known about the early clinical outcomes of patients undergoing emergency coronary artery bypass grafting (CABG) performed by cardiothoracic trainees. **Method:** All patients who underwent first-time, isolated emergency CABG in the United Kingdom between 1996 and April 2019 were identified from the National Adult Cardiac Surgery Audit database. Trends in surgical operator grade (trainee or consultant), early clinical outcomes, and the use of surgical techniques (on-pump versus off-pump) were evaluated. **Results:** A total of 7494 patients were included in the study. The median age was 67.9 years (interquartile range (IQR): 59.3–74.8), and 71% were male. Of these, 983 patients (13.1%) underwent emergency CABG performed by a surgeon in training. The proportion of emergency procedures performed by trainees fluctuated around 10% in 2000, decreased to 6.1% in 2002, and peaked at 20.6% in 2008. After propensity score matching, no differences were observed between trainees and consultants in mortality (9.3% vs. 7.1%; $p = 0.073$), incidence of return to theatre for bleeding (5.0% vs. 6.1%; $p = 0.28$), need for postoperative dialysis (6.2% vs. 7.4%; $p = 0.39$), deep sternal wound infection (0% vs. 1.3%; $p = 0.26$), or number of grafts (2.84% vs. 2.88%; $p = 0.89$). However, trainee-operated cases were associated with greater use of cardiopulmonary bypass (CPB) (92% vs. 87%; $p < 0.001$) and a higher incidence of postoperative cerebrovascular accident (5.3% vs. 2.1%; $p = 0.009$). **Conclusion:** Emergency CABG remains a high-risk operation with substantial in-hospital mortality. Trainees appear to have good exposure as first operators, with no increase in in-hospital mortality compared with consultants. However, trainees make more frequent use of CPB and have a significantly higher incidence of stroke.

Keywords: coronary artery bypass grafting; resident doctor; trainee; cardiothoracic surgery training

1. Introduction and Background

Training in cardiac surgery is overseen by Health Education England and supported by the Society for Cardiothoracic Surgery in Great Britain and Ireland (SCTS), which is an independent, self-funded organisation that serves as the principal body representing the profession. Its mission includes promoting excellence in patient care, steering the educational direction of surgical training, and supporting the professional development of current and future surgeons. Cardiothoracic surgery training in the United Kingdom (UK) encompasses a wide range of disciplines, including adult cardiac surgery, thoracic surgery, and congenital cardiac surgery [1]. The training pathway is structured and rigorous, incorporating competency-based assessments, national examinations, and rotational placements. The curriculum is dynamic and continuously updated to reflect advances in scientific evidence and clinical practice. However, the field faces ongoing challenges, including the need to deliver more structured and intensive subspecialty training within the constraints of limited training years [1].

The increasing complexity of cardiac surgical procedures, alongside rapid technological advancements and the essential requirement for hands-on operative experience, has posed significant challenges in training the next generation of cardiac surgeons. This issue is further intensified by the necessity for trainees to achieve technical proficiency through exposure to high surgical volumes. However, the declining number of coronary artery bypass grafting (CABG) procedures, combined with a reduction in the adoption of off-pump coronary revascularisation techniques, has created a training gap. As a result, training programs now face considerable difficulties in equipping their trainees with comprehensive skills in coronary surgery, particularly in high-risk cases and more advanced revascularisation techniques [2].

Although numerous studies have assessed the clinical outcomes and safety of trainees performing coronary surgery, there is limited evidence focusing specifically on emergency coronary procedures [3,4,5,6]. There is even less data on outcomes for trainees performing emergency on-pump coronary artery bypass grafting (ONCAB) versus off-pump coronary artery bypass grafting (OPCAB).

This study aims to investigate trends in surgical operator grade (trainee or consultant), early clinical outcomes, and the use of surgical techniques (on-pump versus off-pump) in emergency CABG in the UK from 1996 to 2019.

2. Materials and Methods

All patients undergoing urgent isolated emergency CABG in the UK from 1996 to 2019 were identified from

Table 1. The preoperative characteristics of trainee and consultant operators in emergency coronary artery bypass grafting before and after propensity score matching (1996–2019).

Preoperative characteristics	Overall	Pre-PSM			Post-PSM			
	n = 7494	Consultant (n = 6511)	Trainee (n = 983)	*p*-value	Consultant (n = 981)	Trainee (n = 981)	SMD	*p*-value
Age (years), median (IQR)	67.90 (59.30–74.80)	67.90 (59.20–74.80)	68.50 (60.10–75.30)	0.059	68.60 (60.10–75.40)	68.50 (60.20–75.20)	0.038	0.78
Gender, n (%)				0.009				0.68
Male	5332 (71)	4598 (71)	734 (75)		740 (75)	732 (75)	0.0038	
Female	2162 (29)	1913 (29)	249 (25)		241 (25)	249 (25)	0.0188	
BMI, median (IQR)	27.18 (24.40–29.80)	27.20 (24.40–29.70)	27.30 (24.80–30.0)	0.12	27.40 (24.80–29.80)	27.30 (24.80–29.90)	0.0333	0.94
Pulmonary Disease, n (%)				0.056				0.71
No chronic pulmonary disease	6577 (88)	5696 (87)	881 (90)		875 (89)	880 (90)	0.0167	
Chronic pulmonary disease	917 (12)	815 (13)	102 (10)		106 (11)	101 (10)	0.0167	
Diabetes, n (%)				0.037				0.69
Not diabetic	5724 (76)	4970 (76)	754 (77)		767 (78)	764 (77.9)	0.0338	
Diet control	346 (4.60)	296 (4.50)	50 (5.10)		43 (4.40)	43 (4.40)	0.0325	
Oral therapy	883 (12)	755 (12)	128 (13)		115 (12)	118 (12)	0.0363	
Insulin therapy	541 (7.20)	490 (7.50)	51 (5.20)		56 (5.70)	56 (5.70)	0.023	
Smoking, n (%)				0.057				0.75
Never smoked	2553 (34)	2218 (34)	335 (34)		332 (34)	335 (34)	0.0065	
Ex-smoker	3669 (49)	3163 (49)	506 (51)		495 (50)	504 (51)	0.0184	
Current smoker	1272 (17)	1130 (17)	142 (14)		154 (16)	142 (14)	0.0348	
PVD, n (%)				0.066				0.78
No	6453 (86)	5588 (86)	865 (88)		859 (88)	863 (88)	0.0125	
Yes	1041 (14)	923 (14)	118 (12)		122 (12)	118 (12)	0.0125	
Preop AF, n (%)				0.001				0.89
No	7132 (95)	6176 (95)	956 (97)		953 (97)	954 (97)	0.0062	
Yes	362 (4.80)	335 (5.10)	27 (2.70)		28 (2.90)	27 (2.80)	0.0062	
LMS, n (%)				0.63				>0.99
No LMS disease or LMS disease ≤50% diameter stenosis	7484 (100)	6503 (100)	981 (100)		978 (100)	979 (100)	0.0226	
LMS >50% diameter stenosis	10 (0.10)	8 (0.10)	2 (0.20)		3 (0.30)	2 (0.20)	0.0226	
CCS class, n (%)				<0.001				0.99
0	846 (11)	647 (9.90)	199 (20)		204 (21)	197 (20)	0.0178	
1	200 (2.70)	165 (2.50)	35 (3.60)		38 (3.90)	35 (3.60)	0.0165	
2	783 (10)	639 (9.80)	144 (15)		145 (15)	144 (15)	0.0165	
3	1558 (21)	1347 (21)	211 (21)		208 (21)	211 (22)	0.0165	
4	4107 (55)	3713 (57)	394 (40)		386 (39)	394 (40)	0.0165	

Table 1. Continued.

Preoperative characteristics	Overall	Pre-PSM			Post-PSM			
	n = 7494	Consultant (n = 6511)	Trainee (n = 983)	*p*-value	Consultant (n = 981)	Trainee (n = 981)	SMD	*p*-value
NYHA class, n (%)				<0.001				0.92
1	2169 (29)	1850 (28)	319 (32)		330 (34)	318 (32)	0.0261	
2	2285 (30)	1938 (30)	347 (35)		340 (35)	346 (35)	0.0128	
3	1662 (22)	1437 (22)	225 (23)		225 (23)	225 (23)	0	
4	1378 (18)	1286 (20)	92 (9.40)		86 (8.80)	92 (9.40)	0.021	
PCI, n (%)				0.004				0.98
No previous PCI	6061 (81)	5227 (80)	834 (85)		828 (84)	832 (85)	0.0114	
PCI <24 h before surgery	742 (9.90)	671 (10)	71 (7.20)		71 (7.20)	71 (7.20)	0	
PCI >24 h before surgery; same admission	206 (2.70)	179 (2.70)	27 (2.70)		30 (3.10)	27 (2.80)	0.0187	
PCI >24 h before surgery; previous admission	485 (6.50)	434 (6.70)	51 (5.20)		52 (5.30)	51 (5.20)	0.0046	
Ventilated preop, n (%)				0.2				0.81
No	7161 (96)	6214 (95)	947 (96)		943 (96)	945 (96)	0.0109	
Yes	333 (4.40)	297 (4.60)	36 (3.70)		38 (3.90)	36 (3.70)	0.0109	
Cardiogenic shock, n (%)				<0.001				0.47
No	6303 (84)	5425 (83)	878 (89)		866 (88)	876 (89)	0.033	
Yes	1191 (16)	1086 (17)	105 (11)		115 (12)	105 (11)	0.033	
LVEF, n (%)				<0.001				0.7
Very poor (LVEF <21%)	12 (0.20)	12 (0.20)	0 (0)		0 (0)	0 (0)	0	
Poor (LVEF 21–30%)	3949 (53)	3514 (54)	435 (44)		452 (46)	435 (44)	0.0349	
Moderate (LVEF 31–50%)	185 (2.50)	163 (2.50)	22 (2.20)		24 (2.4)	22 (2.20)	0.0138	
Good (LVEF >50%)	3348 (45)	2822 (43)	526 (54)		505 (51)	524 (53)	0.0388	
Neuro Dys, n (%)				0.1				0.24
No	7281 (97)	6318 (97)	963 (98)		953 (97)	961 (98)	0.0578	
Yes	213 (2.80)	193 (3)	20 (2.00)		28 (2.90)	20 (2.00)	0.0578	
Previous MI, n (%)				<0.001				0.77
None	2640 (35)	2232 (34)	408 (42)		418 (43)	406 (41)	0.0248	
One	3962 (53)	3506 (54)	456 (46)		440 (45)	456 (46)	0.0327	
Two or more	892 (12)	773 (12)	119 (12)		123 (13)	119 (12)	0.0125	
Inotropes				0.01				0.81
No	6674 (89)	5775 (89)	889 (91)		894 (91)	897 (91)	0.0109	
Yes	820 (11)	736 (11)	84 (8.50)		87 (8.90)	84 (8.60)	0.0109	
Nitrates				0.97				0.89
No	3457 (46)	3003 (46)	454 (46)		457 (47)	454 (46)	0.0061	
Yes	4037 (54)	3508 (54)	529 (54)		524 (53)	527 (54)	0.0061	
EuroSCORE II, median (IQR)	3.36 (1.96–7.07)	3.47 (2.00–7.25)	2.64 (1.73–5.30)	<0.001	2.85 (1.72–5.53)	2.64 (1.73–5.30)	0.003	0.49

PSM, propensity score matching; SMD, standardised mean difference; IQR, interquartile range; BMI, body mass index; PVD, peripheral vascular disease; AF, atrial fibrillation; LMS, left main stem disease; CCS, canadian cardiovascular society scale; NYHA, New York Heart Association functional class; PCI, percutaneous coronary intervention; LVEF, left ventricular ejection fracture; MI, myocadial infarction.

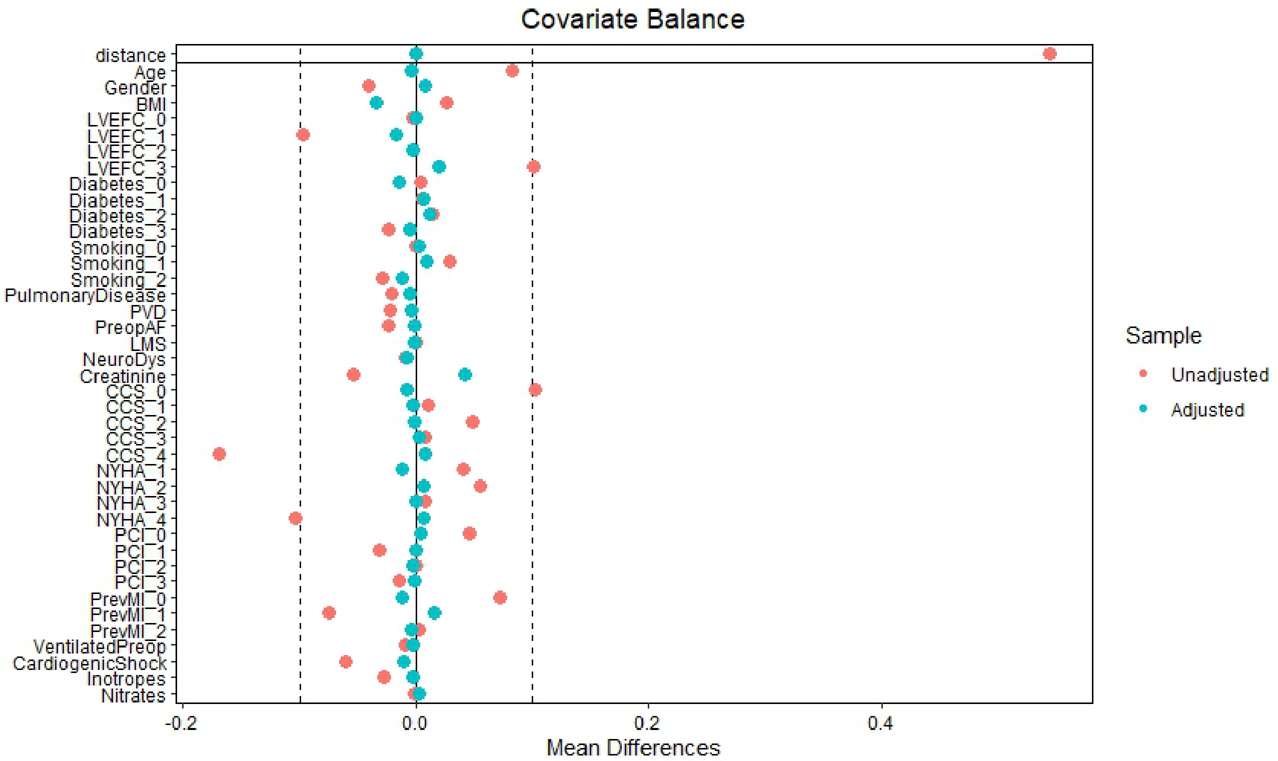

Fig. 1. Love plot depicting the standard mean differences of the baseline covariates before and after propensity score matching.

the National Adult Cardiac Surgery Audit (NACSA) database. This database prospectively collect data on all major heart operations performed on National Health Service (NHS) patients in the UK since April 1996. Details regarding the variable definitions and structure of the NACSA database have been described previously [7]. Specifically, mortality was defined as mortality within the same index admission. Patients were categorised into two groups: (a) consultant surgeons or (b) trainee surgeons. Individuals who had non-isolated emergency CABG or prior cardiac surgery were excluded. Propensity score matching (PSM) was utilised to compare trainees and consultants as primary surgeon. The primary operator was determined according to the Joint Committee on Surgical Training (JCST) criteria, which apply across all surgical specialities in the United Kingdom and Ireland [8]. Specifically, in coronary surgery, a trainee is considered the primary operator if they perform the essential parts of the procedure, completing more than 50% of the anastomosis.

2.1 Statistical Analysis

Normality testing was conducted using the Shapiro-Wilk test. Continuous variables are reported as mean with standard deviation (SD) for parametric data or median and interquartile range (IQR) for non-parametric data. Categorical variables are reported as frequencies and percentages. Group comparisons were performed using Pearson's chi-squared test for categorical variables, Wilcoxon rank-sum test for medians of two independent continuous samples, and Student's *t*-test for means of two independent continuous samples.

PSM was conducted to establish a quasi-experimental design by balancing measured confounding variables between the two groups. A 1:1 nearest neighbour matching without replacement was applied, using a caliper width of 0.2 standard deviations of the logit of the propensity scores, based on preoperative characteristics (Table 1). After matching, covariate balance was assessed using standardised mean differences, with an acceptable threshold defined as <0.1. The effectiveness of PSM was visualised with a love plot, showing propensity scores before and after matching (Fig. 1). Statistical significance was defined as $p < 0.05$. Statistical analyses were performed using R version 4.2.3 from R Foundation for Statistical Computing (Vienna, Austria) and RStudio version 1.4.1103 from RStudio, PBC (Boston, MA, USA). Graphs and tables were created with RStudio and Microsoft Office 365 (Version 16.0.14026, 64-bit).

3. Results

A total of 7494 patients were included in the study. The median age was 67.9 years (IQR: 59.3–74.8), 71% were male, and the median body mass index (BMI) was 27.2 (IQR: 24.4–29.8). Among these, 983 (13.1%) underwent emergency CABG performed by a surgeon in training. The proportion of emergency CABG procedures performed by

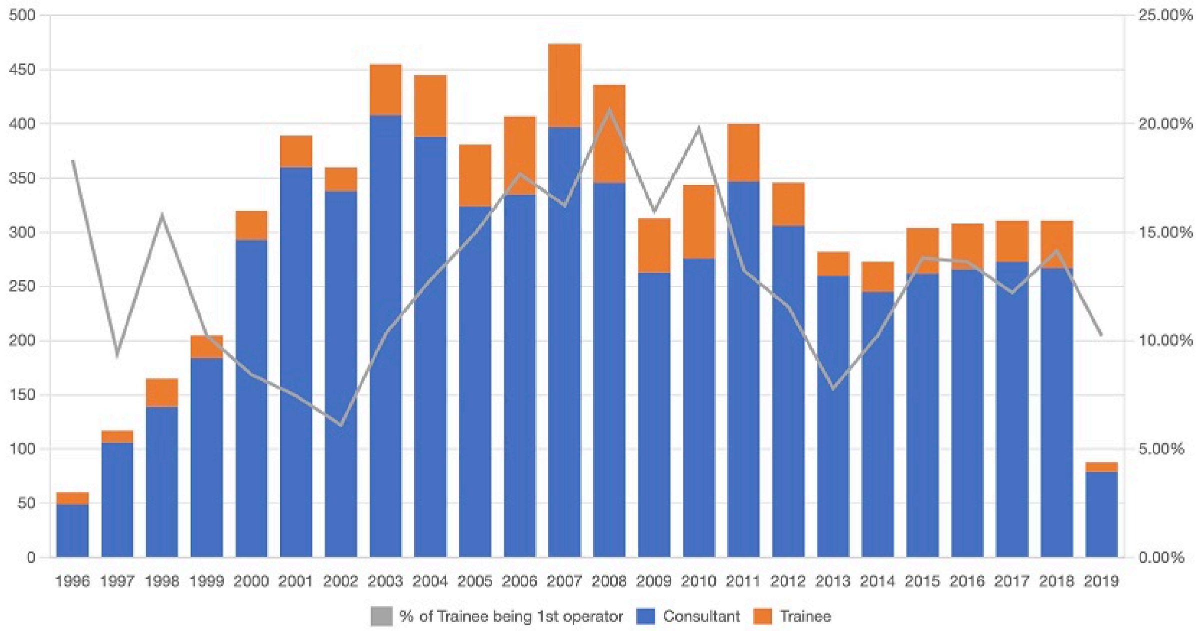

Fig. 2. The number of emergency coronary artery bypass graft procedures performed by a consultant (blue) and trainee (orange), and the percentage of trainees acting as first operators (grey) in the UK from 1996 to April 2019.

trainees fluctuated around 10% in 2000, decreased to 6.1% in 2002 and subsequently increased to a peak of 20.6% in 2008. This was followed by a gradual decline to 7.8% in 2013, where in 2019 trainees perform around 13% of all total emergency CABG procedures (Fig. 2).

3.1 Perioperative Characteristics (1996–2019)

PSM created 2 equally sized groups (n = 981, consultant and n = 981, trainee) and the preoperative characteristics are shown in Table 1. After PSM, there was no statistical significance in all variables assessed. There were no differences in age between consultant vs trainee; (68.6 (IQR: 60.1–75.4 vs; 68.5 (IQR: 60.2–75.2)) years, p = 0.78), female gender (25% vs 25%, p = 0.68) and BMI (27.4 (IQR: 24.8–29.8) vs 27.3 (IQR: 24.8–29.9), p = 0.94).

3.2 Intra- and Postoperative Characteristics

The median cardiopulmonary bypass (CPB) time in the consultant group was 80 (IQR: 59–107 min) and 79 (IQR: 60–100 min) in the trainee group, p = 0.28. The median aortic cross-clamp time in the consultant group was 41 (IQR: 27–60 min) and 42.5 (IQR: 30.5–56 min) in the trainee group, p = 0.69. The overall mortality rate for all isolated emergency CABG was 11% over the study period.

After PSM, trainees acting as first operator when compared with consultants as first operator, were associated with a higher incidence of postoperative Cerebrovascular Accident (CVA), (Transient ischaemic attack (TIA): 2.1% vs 1.1%, stroke: 3.2% vs 1.0%, p = 0.009) and a greater number of cases were performed using the CPB machine (92% vs 87%, p < 0.001). No differences were seen between trainees and consultants in mortality (9.3% vs 7.1%, p = 0.073), incidence of return to theatre (9.1% vs 10%, p = 0.38), incidence of return to theatre with bleeding and/or tamponade (5% vs 6.1%, p = 0.28), postoperative dialysis (6.2% vs 7.4%, p = 0.39), postoperative deep sternal wound infection (0% vs 1.3%, p = 0.26), number of grafts (2.84% vs 2.88%, p = 0.89), number of arterial grafts (0.84% vs 0.81%, p = 0.058) and postoperative deep sternal wound infection requiring treatment (0.01% vs 0%, p = 0.51) (Table 2).

4. Discussion

Our study suggests that trainees in the UK are adequately exposed to emergency CABG as first operators. This is not associated with a higher in-hospital mortality when compared with consultants as first operators. However, trainees make more frequent use of CPB and have a significantly higher incidence of stroke.

Cardiothoracic surgery training in the United Kingdom remains a highly sought-after and competitive speciality [1]. Training programmes aim to develop and mentor surgeons who are both clinically competent in decision-making and technically skilled in performing procedures while managing intraoperative or postoperative complications [9]. Although reductions in training hours have limited theatre exposure, a review by Mahesh et al. [10] in a high-volume cardiac surgery centre, demonstrated adequate training standards were still maintained despite fewer operative hours. The high service demands of the UK National

Table 2. The intra- and postoperative outcomes between trainees and consultants performing emergency coronary artery bypass grafting before and after propensity score matching (1996–2019).

Intra- and postoperative characteristics	Overall	Pre PSM			Post-PSM		
	n = 7494	Consultant (n = 6511)	Trainee (n = 983)	*p*-value	Consultant (n = 981)	Trainee (n = 981)	*p*-value
CPB, median (IQR)	80 (59–106)	80 (59–107)	79 (60–100)	0.28	78 (59–105)	79 (60–100)	0.77
Xclamp, median (IQR)	41 (28–60)	41 (27–60)	42.50 (30.50–56.00)	0.69	41 (28–57)	42.50 (30–56)	0.33
Mortality, n (%)	823 (11)	754 (12)	69 (7.10)	<0.001	90 (9.30)	69 (7.10)	0.073
RTT, n (%)	600 (9.40)	528 (9.50)	72 (9)	0.7	87 (10)	72 (9.10)	0.38
RTT, bleeding, tamponade, n (%)	408 (5.40)	359 (5.50)	49 (5)	0.5	60 (6.10)	49 (5)	0.28
Postop CVA, n (%)				<0.001			0.009
None	6182 (97)	5417 (98)	765 (96)		769 (98)	765 (96)	
Transient Stroke	67 (1.10)	57 (1)	10 (1.20)		9 (1.10)	10 (2.10)	
Permanent Stroke	106 (1.70)	80 (1.40)	26 (3.20)		8 (1.00)	26 (3.20)	
Postop dialysis, n (%)	539 (8.80)	497 (9.10)	42 (6.20)	0.013	57 (7.40)	42 (6.20)	0.39
Postop DSWI, n (%)	19 (1.10)	19 (1.20)	0 (0)	0.25	3 (1.30)	0 (0)	0.26
Use of CPB, n (%)	6552 (87)	5646 (87)	906 (92)	<0.001	853 (87)	904 (92)	<0.001
Number of grafts, n (%)				0.79			0.89
1	631 (8.50)	554 (8.60)	77 (7.90)		83 (8.60)	77 (7.90)	
2	1759 (24)	1535 (24)	224 (23)		206 (21)	224 (23)	
3	3201 (43)	2773 (43)	428 (44)		429 (44)	427 (44)	
4	1496 (20)	1293 (20)	203 (21)		211 (22)	202 (21)	
5	212 (2.90)	183 (2.80)	29 (3.00)		29 (3.00)	29 (3.0)	
6	31 (0.40)	29 (0.50)	2 (0.20)		3 (0.30)	2 (0.2)	
Arterial Grafts, n (%)				<0.001			0.058
1	4673 (62)	3983 (61)	690 (70)		658 (67)	688 (70)	
2	440 (5.90)	393 (6.00)	47 (4.80)		75 (7.60)	47 (4.80)	
3	46 (0.60)	42 (0.60)	4 (0.40)		6 (0.60)	4 (0.40)	
Postop DSWI treatment, n (%)				>0.99			0.51
None	1790 (99)	1612 (99)	178 (100)		230 (99)	178 (100)	
Conservative Rx (Vac Pump)	9 (0.50)	9 (0.60)	0 (0)		2 (0.90)	0 (0)	
Surgical debridement	8 (0.40)	8 (0.50)	0 (0)		1 (0.40)	0 (0)	

CPB, cardiopulmonary bypass; SD, standard deviation; RTT, Return to theatre; CVA, Cerebrovascular Accident; DSWI, Deep sternal wound infection.

Health Service make resource planning and theatre allocation for trainees challenging. Trainees may operate more slowly than their trainers, and increasing emphasis on efficiency and patient flow within surgical departments can further restrict operative opportunities. An earlier review comparing operative times between consultants and trainees in coronary surgery found no differences in hospital costs or overall mortality; although anastomoses were completed more quickly by consultants, the overall operation duration was on average 9 minutes longer [11]. Nevertheless, a substantial body of literature demonstrates a positive correlation between surgeon case volume and patient outcomes, with lower-volume surgeons (often including trainees), generally associated with less favourable outcomes [12].

Cardiac surgery requires close supervision and trainers who are comfortable allowing trainees to perform part or all of a procedure [11]. Across the United States, the United Kingdom, and other healthcare systems, increasing scrutiny of surgeon and unit-specific outcomes, while intended to improve quality of care, may inadvertently limit surgical training opportunities [9,13]. Trainers must therefore balance their responsibility to provide optimal patient care with their duty to teach. Trainee participation frequently depends on the consultant's discretion and confidence, which is often influenced by their own training experiences [14]. Furthermore, not all skilled surgeons are necessarily effective trainers [15]. Multiple factors may hinder effective surgical training, including individual operating preferences, time pressures in theatre, the quality of the trainer–trainee relationship, and inappropriate case selection.

Confidence in the operating theatre is closely related to operative volume, technical skill and the trainer-trainee relationship [9]. Notably, previous reports suggest that the cumulative experience and established working relationship between a consultant-trainee pair may exert a greater influence on operative outcomes than the individual experience of either surgeon alone [16]. A commonly adopted strategy involves consultants selecting cases and coronary targets that are appropriate for the trainee's level of experience and technical proficiency, thereby supporting optimal patient outcomes, particularly in an increasing elderly and high-risk population. Training is typically structured to progress gradually, allowing residents to build confidence and competence over time. Consistent mentorship, where trainees work closely with trainers familiar with their development and committed to refining their skills, is therefore essential for fostering surgical excellence [2].

Tolis Jr et al. [17] conducted a retrospective study matching 100 cardiac operations in which patients were performed entirely by either consultants or trainees to avoid any ambiguity regarding operative responsibility. Although, CPB and aortic cross-clamp (ACC) times were longer in the trainee group, clinical outcomes were similar [17]. Likewise, Escorel Neto et al. [16] reported lower mortality in the trainee cohort despite longer CPB and ACC durations, without increases in intensive care or overall hospital length of stay. Consistent with these findings, CPB times in our study were comparable between consultants and trainees (78 [59–105] vs 79 [60–100], $p = 0.77$), as were ACC times (41 [28–57] vs 42.5 [30–56] minutes, $p = 0.33$), with no difference in mortality (9.3% vs 7.1%, $p = 0.073$).

Similarly, a Papworth-based group performed a 10-year matched analysis of emergency cardiac surgery, demonstrating shorter CPB time in resident-led procedures compared with consultant-led cases, with patients in both groups having comparable EuroSCORE II values [18]. Consistent with this, our analysis showed no significant difference in operative risk between the groups: EuroSCORE II was 2.85 (1.72–5.53) in the consultant cohort and 2.64 (1.73–5.30) in the trainee cohort, $p = 0.49$.

In a propensity score-matched analysis by Escorel Neto et al. [16] comparing operative outcomes between consultants and their trainees, operative mortality (OR 0.59, $p = 0.009$) and neurological complications (OR 0.66, $p = 0.010$) were significantly lower in the trainee group. In contrast, within our emergency CABG cohort after matching, trainees demonstrated a higher incidence of CVA ($p = 0.009$). Trainees were also more likely to perform procedures using CPB (92% vs 87%, $p < 0.001$) and the greater degree of aortic handling with on-pump surgery may partially explain this observation. Substantial evidence indicates that CPB, compared with off-pump surgery, is associated with an increased risk of stroke. Supporting the safety of supervised trainee practice, Ascione et al. [19] reported that high-risk OPCAB procedures performed by trainees were not associated with increased mortality compared with consultant performed operations, although postoperative stays were longer and transfusions were higher. At 24 months of follow-up, Kaplan–Meier estimates of cumulative mortality were 10.5% (95% CI: 7.7%–14.2%) in the consultant group and 6.4% (95% CI: 3.8%–10.9%) in the trainee group [19].

A review paper by Lee et al. [20] explained that, based on organisational and management theory, patients who underwent percutaneous coronary interventions (PCIs) in large teaching hospitals had lower rates of repeat revascularisation than patients whose procedures were carried out in hospitals with limited or no teaching involvement. This highlights how training residents may complement patient care, as trainers are often given greater responsibility while also reinforcing their existing knowledge, ultimately contributing to positive patient outcomes [20].

Little is known about clinical outcomes among trainees performing emergency CABG, although no increased mortality risk has been shown when trainees operate in high-risk cases. Given the presence of numerous confounding factors influencing patient selection, many of which may not be fully captured in the available data, it is likely that residual selection bias persisted even within matched analyses. This may account for the consistently lower observed mortality rates. We believe the careful selection of cases, combined with the active supervisory role of consultant surgeons who can intervene or guide trainees when needed, appears essential to ensuring both favourable clinical outcomes and effective surgical training.

5. Limitations

This study is subject to several intrinsic limitations. Its retrospective design based on prospectively collected data makes it vulnerable to selection and observational biases. Factors such as lesion complexity, anatomical considerations (e.g. coronary anatomy), and individual trainee technical ability are not captured in the NACSA database. There is also potential disparity between gender, race or the centre the trainee is operating; this data has also not been recorded in the database. Data completeness also posed challenges, as the database relies on manual input from healthcare professionals, with some postoperative outcomes and non-mandatory fields missing. Another limitation is the absence of long-term follow-up, outcomes such as repeat revascularisation, and major adverse cardiac events could not be assessed. Finally, while propensity score matching reduced measured confounding, residual selection bias from unmeasured variables, such as surgical expertise, may persist. Finally, it is likely that a consultant may have often passed their trainees "easier", more straightforward cases. Despite these limitations, our study highlights an important issue in surgical education.

6. Conclusion

Our data show fluctuations in the number of trainees acting as primary operators in emergency CABG over a 23-year period. This variability is likely multifactorial and highlights the ongoing debate about when training in emergency CABG is appropriate. Significantly, trainee-operated cases were not associated with an increase in in-hospital mortality compared with consultant-operated cases. However, trainees were more likely to use on-pump surgery and had a higher incidence of stroke compared to consultants. Given that emergency CABG remains a critical procedure, trainees must gain sufficient exposure to develop the skills required to perform it independently and safely as future independent consultant surgeons.

Availability of Data and Materials

The data underlying this article were provided by NICOR by permission. Data will be shared on request to the corresponding author with permission from NICOR.

Author Contributions

Designed the research study: KS, JC, GDA; Data collecting: KS, JC; Data analysis: KS, JC; Writing and final checks of the article: KS, JC, GDA. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study formed part of an existing research project approved by the Health Research Authority and Health and Care Research Wales. Given the retrospective nature of the National Institute for Cardiovascular Outcomes Research (NICOR) database analysis, the requirement for individual patient consent was waived in accordance with research governance guidelines (IRAS ID: 278171). The research was conducted in compliance with the ethical principles outlined in the 1964 Declaration of Helsinki and its subsequent revisions.

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Conflicts of Interest

The authors declare no conflicts of interest. Gianni D Angelini is serving as one of the Editorial Board members of this journal. We declare that Gianni D Angelini had no involvement in the peer-review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Prof. Haiyang Li.

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