The Cardiothoracic Surgeon

REVIEW

Open Access

The current state of minimally invasive cardiac surgery in Africa: a systematic review and meta-analysis

Oluwanifemi O. Akintoye[1*], Bukola G. Adu[1], Michael J. Otorkpa[1], Oluwatobi O. Olayode[1], Samuel Fodop[1], Peace O. Alemede[1], Ruth K. Enyong[1], Feziechi C. Anele[1] and Benjamin I. Omoregbee[1,2]

Abstract

Background Globally, the utilisation of minimally invasive techniques has become increasingly prevalent. While traditional open-heart procedures still dominate the landscape, a significant portion of cardiac surgeries are now performed minimally invasively. The aim of this study is to provide an insightful overview of the current state of minimally invasive cardiac surgery in Africa.

Main body A comprehensive database search was performed on PubMed, African Journal Online, Google Scholar, and Scopus to identify published data reporting on outcomes of minimally invasive cardiac surgery in Africa, from inception till June 2024. We used the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines to undergo this study. The primary outcomes of interest were in-hospital mortality and overall mortality. Data were pooled together and analysed using a random effect model for meta-analysis with R software. Out of a total of 2309 articles identified, only fourteen papers met our inclusion criteria following deduplication and screening. The four countries with published research include Egypt, South Africa, Tanzania, and Morocco, with a total sample size of 1357 patients. The meta-analysis of the reported outcomes produced a pooled in-hospital mortality prevalence of 1.18%, while the pooled overall mortality prevalence was 2.23%. There was no statistically significant difference in outcomes between the mini sternotomy and the full sternotomy group.

Conclusion The pooled outcomes of minimally invasive cardiac surgery in Africa are comparable to those in other regions. However, there are several socio-economic factors limiting its widespread practice in Africa.

Keywords Minimally invasive cardiac surgery, Keyhole cardiac surgery, Mini sternotomy

Background

Minimally invasive cardiac surgery (MICS) has sparked a revolution in the realm of cardiac intervention worldwide. It has emerged as a transformative approach in the management of various cardiac pathologies. Despite initial hesitancy within the field, cardiac surgery has swiftly embraced these innovative approaches, showcasing remarkable adaptability and progress [1]. Globally, the utilisation of minimally invasive techniques has become increasingly prevalent, with ongoing efforts focused on enhancing innovation [2]. While traditional open-heart procedures still dominate the landscape, a significant portion of cardiac surgeries, including mitral valve surgeries, coronary artery bypass grafts, and aortic valve replacements, are now performed minimally invasively [3]. Studies consistently affirm the benefits of this approach, highlighting diminished surgical trauma at the operative site, fewer blood loss and transfusions,

*Correspondence:
Oluwanifemi O. Akintoye
akintonife@yahoo.com
[1] Cardiothoracic Surgery Community, Surgery Interest Group of Africa, Lagos, Nigeria
[2] Hull University Teaching Hospital NHS, Kingston Upon Hull, UK

reduced pain, quicker mobilisation, shorter hospital stay, and faster recovery rate [4–6].

Cardiovascular diseases (CVDs) remain the leading cause of death in Africa, and they account for 38.9% of deaths from non-communicable diseases in the continent [7]. As Africa contends with a rising burden of CVDs, the need for effective and accessible cardiac treatments grows ever more pressing [8]. Like all developing regions, Africa grapples with unique challenges hindering the widespread adoption and advancement of MICS [9]. The financial and infrastructural constraints in the low-resource African setting pose formidable barriers to the progress of MICS [10]. However, we believe pockets of advancement have emerged across the continent, where the practice and utilisation of minimally invasive cardiac surgery have been established. However, the adoption of minimally invasive MICS in Africa appears to lean towards palliative care interventions [11, 12]. The aim of this study is to provide an insightful overview of the current state of MICS in Africa. Understanding the unique dynamics of MICS in Africa is crucial for improving access to effective cardiac interventions. This research aims to explore and shed light on the accessibility, outcomes, and factors limiting the extensive practice of MICS in Africa.

Methods

This research was conducted based on the Preferred Reporting System for Systematic Review and Meta-analysis (PRISMA) guidelines. An extensive literature search was undergone on multiple databases to locate suitable articles that met our study eligibility criteria. The search strategy was jointly developed by all authors. The search duration was from inception up till June 2024 on the following search engines: PubMed, Scopus, African Journal Online, and Google Scholar. Additionally, the reference lists of eligible studies were examined. Supplementary Table S1 shows the search strategy of this study, including the keywords and MesH terms utilised for the study.

Inclusion criteria

For this review, we aimed to include all research articles, observational or interventional, that reported on any type of MICS carried out in any of the 54 African countries. We included studies carried out via thoracotomy or mini sternotomy. Studies carried out on both the paediatric and adult populations were included. We included only papers with full text written in English as we did not have resources for interpretation.

Exclusion criteria

We excluded papers that reported on any of the following article types: case reports, case series, abstract only, commentaries, systematic reviews, and letters to the editor. We excluded papers written in other languages apart from English, studies carried out in the non-human population, and studies done in the non-African population. Studies that reported on transcatheter valvular procedures were also excluded as these are interventional cardiology procedures.

Data extraction and analysis

Search results from search engines were downloaded into rayyan.ai, [13] a software used for screening and deduplication. Screening was done by eight independent authors, and inconsistent decisions were solved by team discussion to reach a consensus. The initial screening process involved article title and abstract screening, which was followed by full-text screening. Articles that met the inclusion criteria were exported to an Excel spreadsheet for data extraction. Two independent authors assessed the quality of each included study using the Newcastle–Ottawa scale, and disparities in assessment were discussed to reach a consensus. Qualities of the research papers assessed include selection process, comparability method, and the outcomes reported by each study.

Variables of interest

The following information were extracted from the included paper for analysis and review: author, year of publication, journal, country, study design, follow-up period, age, sex, comorbidities (such as hypertension, diabetes mellitus, dyslipidaemia, chronic obstructive pulmonary disease (COPD), smoking, atrial fibrillation, New York Heart Association (NYHA) classification, and renal dysfunction), Euro-score, and left ventricular ejection fraction (LVEF). Operative variables included cross-clamp time, cardiopulmonary bypass time, operative time, and type of minimally invasive access.

Mortality outcome variables analysed include in-hospital mortality and overall mortality. Overall mortality was defined as all reported deaths during the included studies duration, while in-hospital mortality included all deaths reported as occurring in-hospital. Other outcomes analysed include length of intensive care unit (ICU) stay, length of hospital stay, post-operative complications such as conversion to open surgery, post-operative stroke, wound infection, and re-exploration for bleeding.

Appropriate summary statistics (mean, counts, and proportions) were used to report the variables of interest and visually represented using tables. For the meta-analysis of outcomes, a single pooled incidence was derived using a random effect model for proportions utilised for the MICS cohort. The random effects model was also used to compare outcomes between the mini sternotomy and full sternotomy groups, assuming heterogenicity among the studies. Tables and forest plots were created as a graphical representation of results. Mean differences were calculated for numerical variables and odd ratios for categorical variables for the endpoints of interest. All statistical analysis was done using R studio software (version 4.3.1 (2023–06-16)—"Beagle Scouts"). A 5% level of significance and 95% confidence interval were utilised. Images were produced using the R studio software.

Results

A total of 2286 records were identified through database searching, and an additional 23 papers were identified from references and citation checks to give a total of 2309 screened articles. After deduplication, 227 papers were found to have been duplicated and excluded from the study. The remaining 2082 papers underwent title and abstract screening against our eligibility criteria. Following this, only 90 papers were identified for full-text screening (86 from the database and 4 from the other source search). Two of the 86 database articles could not be retrieved for full-text screening as efforts to get the full text of the articles were unsuccessful. Full-text screening of the remaining 88 papers led to the exclusion of a further 74 papers, and only 14 studies [6, 11, 12, 14–24] met the criteria for inclusion to our study. The PRISMA flow chart outlining the study selection process is shown in Fig. 1.

Ten of the 14 included research articles were comparative studies, and four were non-comparative studies. Six of the articles compared outcomes of minimal access to full open median sternotomy, while four compared outcomes between different types of minimally invasive access. Three of them were randomised controlled trials, while the others were either prospective (8) or retrospective (2) cohort studies. The Newcastle–Ottawa scale was used to assess the quality of each study, and this is shown in Supplementary Table S2. Of the 54 countries in Africa, only four countries had published research work that met the criteria for inclusion in our study, and they include Egypt, South Africa, Tanzania, and Morocco with majority of 11 (78.6%) of the papers from Egypt. Table 1 shows the characteristics of the studies included in our review. Only 1 (7.1%) study reported on minimally invasive coronary bypass graft, 3 (21.4%) were on mitral valve surgery, 7 (50%) on aortic valve replacement, 1 (7.1%) on double (mitral and aortic) valve surgery, 1 (7.1%) on mixed MICS (atrial septal defect closure, tricuspid valve, and mitral valve surgery), and 1 (7.1%) on neonatal congenital heart surgery (Blalock-Taussig shunt). Minimally invasive

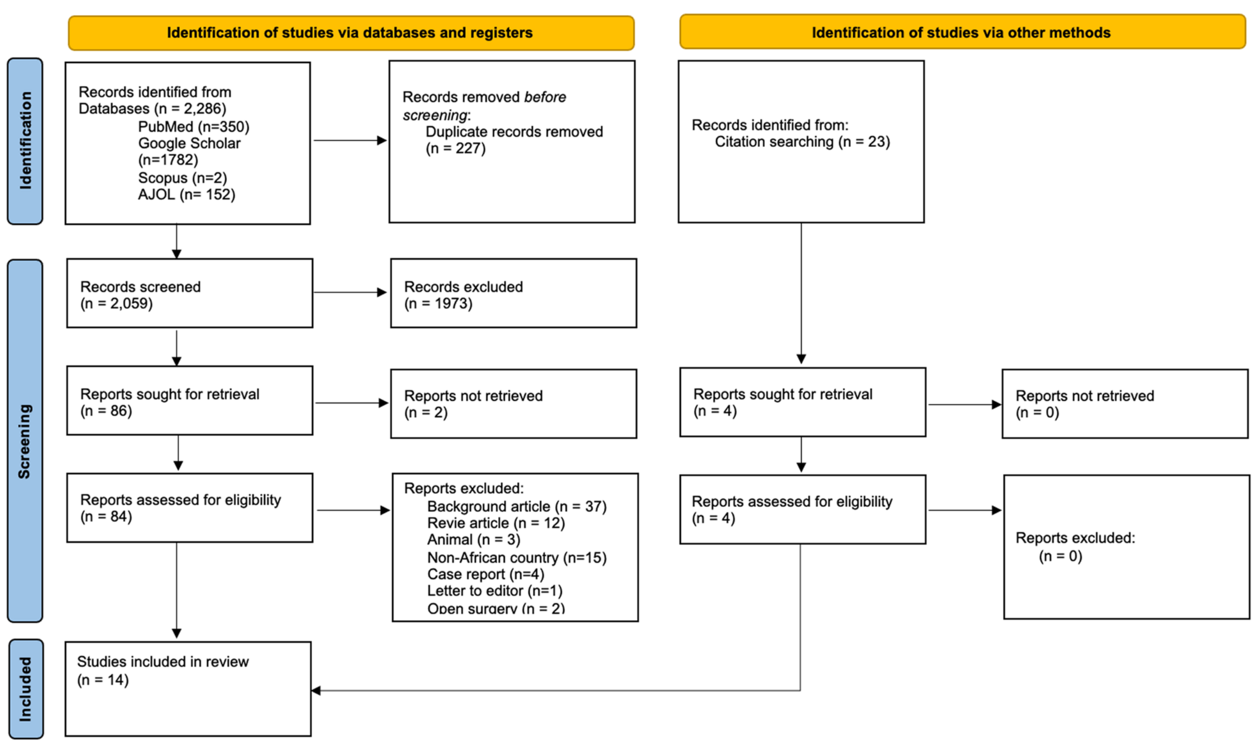


Fig. 1 PRISMA flow chart showing article selection process

Table 1 Characteristics of the papers included in the review

Author	Country	Year of publication	Study design	Sample size (MICS group)	Total sample size	Surgery type	Minimal access type	Comparison
Harris DG et al. [14]	South Africa	2008	Non-comparative prospective cohort	55	55	Coronary graft	Left anterior thoracotomy	No comparison
Ussiri EV et al. [12]	Tanzania	2011	Non-comparative prospective cohort	14	14	Mitral Valvotomy	Mini lateral thoracotomy	No comparison
Attman WG et al. [11]	Egypt	1999	Non-comparative prospective cohort	12	12	Mitral commissurotomy	Mini lateral thoracotomy	No comparison
Alkady H et al. [6]	Egypt	2021	Comparative prospective cohort	72	150	Double (Aortic + Mitral) valve surgery	Upper mini sternotomy	Min sternotomy vs full sternotomy
Zalle et al. [15]	Morocco	2021	Comparative prospective cohort	18	36	Aortic valve replacement	Mini sternotomy or Right Mini thoracotomy	Minimally invasive vs full sternotomy
Abd Al Jawad M et al. [16]	Egypt	2022	Comparative prospective cohort	189	189	Aortic valve replacement	J-mini sternotomy, Min thoracotomy (right anterior)	Mini sternotomy vs mini thoracotomy
Sanad, M. et al. [17]	Egypt	2020	Comparative prospective cohort	50	102	Aortic valve replacement	T-shaped hemi sternotomy	Mini sternotomy vs full sternotomy
Mourad F et al. [18]	Egypt	2021	Comparative retrospective study	260	260	Aortic valve replacement	J-shaped mini sternotomy, right mini thoracotomy	Mini sternotomy vs mini thoracotomy
Bakr Ali MK et al. [19]	Egypt	2023	Comparative prospective cohort	45	90	Aortic valve replacement	Upper J-shaped sternotomy	Mini sternotomy vs full sternotomy
El-Fiky MM et al. [20]	Egypt	2000	Randomised control trial	50	100	Mitral valve surgery	Right antero-lateral thoracotomy	Mini right anterolateral thoracotomy vs full sternotomy
Moustafa AM et al. [21]	Egypt	2007	Randomised control trial	30	60	Aortic valve replacement	Mini sternotomy	Mini sternotomy vs full sternotomy
El Midany, A.A.H., et al. [22]	Egypt	2019	Non-comparative prospective cohort	50	50	Modified Blalock-Taussig shunt	J-shaped upper mini sternotomy	No comparison
Torky, M.A et al. [23]	Egypt	2021	Comparative retrospective study	72	137	Aortic valve replacement	J-shaped mini sternotomy	Mini sternotomy vs full sternotomy
El Adel, M et al. [24]	Egypt	2022	Randomised control trial	102	102	ASD closure, mitral valve replacement, and tricuspid valve replacement	Peri-areolar, infra-mammary	Peri-areolar minimally invasive (PAMI) vs infra-mammary approach

access via mini thoracotomy and mini sternotomy was reported across the included studies. Five (35.7%) studies reported the use of only upper mini sternotomy (either J-shaped or T-shaped). Four types of mini thoracotomy were reported, lateral, antero-lateral, left anterior, and right anterior mini thoracotomy.

Demographic characteristics

The 14 studies included in the review had a total of 1357 study participants. Of these, 1019 (75.15) underwent MICS, while the others were the comparison participants who underwent the conventional full median sternotomy. Table 2 shows the demographic characteristics of the 1019 participants who underwent MICS. The average

Table 2 Pre-operative and operative characteristics of patients' minimally invasive cohort

Characteristics	Number of studies reporting variable	*n*/*N* (%) or mean ± SD
Mean age (years)	14/14	40.05 ± 11.03
Male	13/14	443/1001 (44.3%)
Body surface area (m^2)	3/14	5.21 ± 0.83
Body mass index (kg/m^2)	5/14	138.75 ± 25.22
Hypertension	6/14	348/644 (54.0%)
Diabetes mellitus	8/14	270/818 (33.0%)
Dyslipidaemia	4/14	87/247 (35.2%)
COPD	4/14	27/249 (10.8%)
Smoking	3/14	28/192 (14.6%)
Pre-op atrial fibrillation	4/14	22/206 (10.7%)
Chronic kidney disease	3/14	12/177 (6.8%)
Cerebrovascular disease	3/14	8/194 (4.1%)
Mean LVEF (%)	8/14	55.82 ± 9.44
LVEF < 30%	2/14	4/105 (3.8%)
LVEF 30–49%	2/14	26/105 (24.8%)
LVEF > 50%	2/14	75/105 (71.4%)
Peripheral vascular disease	2/14	13/127 910.2%)
NYHA I-II	7/14	300/669 (44.8%)
NYHA III-IV	7/14	369/669 (55.2%)
Euro-Score	4/14	5.02 ± 3.84
Rheumatic heart disease	3/14	124/140 (88.6%)
Type of surgery	14/14	
Mitral valve surgery	-	155 (15.2%)
Aortic valve replacement	-	664 (65.2%)
AVR + MVR	-	72 (7.1%)
ASD closure	-	22 (2.2%)
Tricuspid valve surgery	-	1 (0.1%)
Modified Blalock-Taussig shunt	-	50 (4.9%)
Coronary artery bypass	-	55 (5.4%)
Type of minimal access	14/14	
Left anterior mini thoracotomy	-	55 (5.4%)
Lateral thoracotomy	-	26 (2.6%)
Right anterior or right mini thoracotomy	-	227 (22.3%)
Right antero-lateral	-	50 (4.9%)
Upper mini sternotomy (T- or J-shaped)	-	559 (54.9%)
Peri-areolar	-	53 (5.2%)
Infra-mammary	-	49 (4.8%)
Use of cardiopulmonary bypass	14/14	
Off-pump	-	131 (12.9%)
On-pump	-	888 (87.1%)
CPB (mins)	10/14	102.29 ± 29.49
Cross-clamp time (mins)	10/14	67.08 ± 18.41
Operative time (mins)	6/14	136.69 ± 15.98
Incision length (cm)	6/14	7.41 ± 0.75

n, total number of participants with characteristic of interest; *N*, total sample size of participants with which the presence or absence of characteristics is reported; *% or mean*, continuous variables reported as mean and categorical variables as percentages; *COPD* Chronic obstructive pulmonary disease, *LVEF* Left ventricular ejection fraction, *NYHA* New York Heart Association, *MVR* Mitral valve replacement, *AVR* Aortic valve replacement, *CPB* Cardiopulmonary bypass time, *ASD* Atrial septal defect age of the MICS participants was 40.05 ± 11.03 years. The studies by Ussiri et al. [12] and Attama et al. [11] were carried out on both paediatric and adult participants, while the paper by El Midany et al. [22] was only on neonatal patients. The other 11 studies involved only adult participants. Majority (558, 55.7%) of the participants were females. In studies that reported comorbidities, 348 (54.0%) had hypertension, 270 (33.0%) had diabetes mellitus, 87 (35.2%) had hypercholesterolemia, 27 (10.8%) had COPD, 12 (6.8%) had chronic renal dysfunction, and 22 (10.7%) had pre-operative atrial fibrillation. The mean LVEF was 54.82 ± 9.44%. Majority (369, 55.2%) of the patients had reported NYHA classification III or IV.

Operative features

Majority (892, 85.5%) of the study participants underwent valve surgery, with 664 (65.2%) isolated aortic valve replacement, 155 (15.2%) mitral valve surgery, 1 (0.1%) tricuspid valve surgery, and 72 (7.1%) double valve replacement. Only 55 (5.4%) patients underwent coronary artery bypass graft, while the rest had congenital heart surgery. Mechanical valve replacement was the most common type of valve replacement surgery. Types of mitral surgery performed included valvotomy, commissurotomy, and annuloplasty. Over half (559, 54.9%) of the participants underwent mini sternotomy. All mini sternotomy were via an upper sternal approach with either T-shaped or J-shaped mini sternotomies. Four types of mini thoracotomies were identified, left anterior 55 (5.4%), lateral 26 (2.6%), right anterior 227 (22.35), and right anterio-lateral 50 (4.9%). A high proportion (888, 87.1%) of the MICS were performed with the use of cardiopulmonary bypass. The mean bypass time in patients who had on-pump surgery was 102.29 ± 29.49 min, while the mean aortic cross-clamp time and operative time were 67.08 ± 18.41 and 136.69 ± 15.98 min, respectively. Table 2 also shows the operative data of the study participants.

Post-operative outcomes

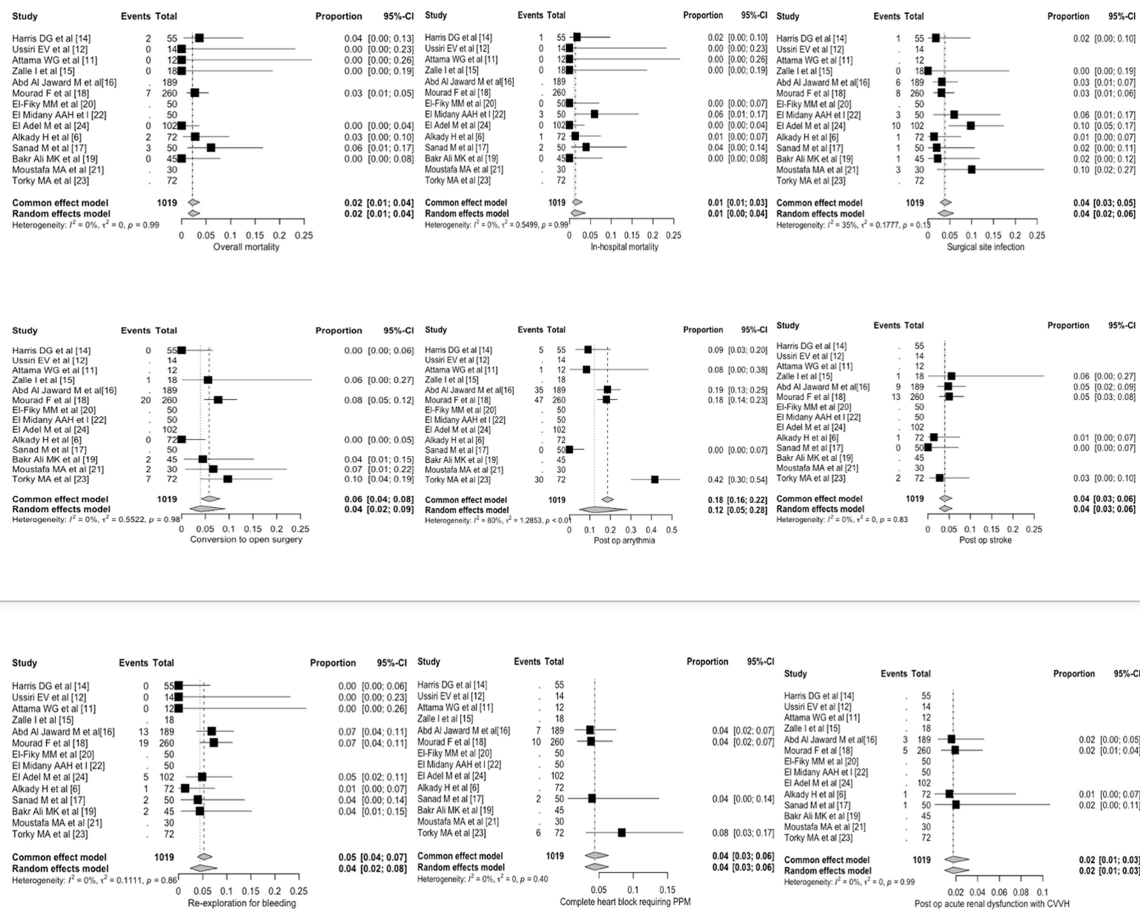
The prevalence of the post-operative outcomes of the MICS cohort was pooled together using the random effects model and is shown in Table 3. Ten studies reported on in-hospital mortality with a pooled prevalence of 1.18% (95% confidence interval (CI) 0.3–4.59%). The pooled overall mortality was calculated to be 2.23% (95% CI 1.21–4.08%). The post-operative complication with the highest prevalence was post-operative arrhythmia with a pooled prevalence of 12.15% (95% CI 4.61–28.35%). Thirty-two patients were reported in 7 studies to have needed conversion from MICS to open surgery. The pooled prevalence of conversion to open surgery was 4.01% (95% CI 1.70–9.18%). In addition, 42 patients required re-exploration for bleeding in 9 studies that reported on this outcome (pooled prevalence 4.46% 95% CI 2.43–8.06%). The pooled mean length of ICU stay and hospital stay was 2.56 (95% CI 1.78–3.34) days and 8.43 (6.94–9.92) days, respectively (Fig. 2).

Five studies ($n = 539$) compared mini sternotomy to conventional full median sternotomy. Table 4 summarises the outcomes of these five studies comparing mini sternotomy to full sternotomy. All five studies reported on CPB time and cross-clamp time, while only three of the studies reported on operative time. There were no statistically significant differences in CPB time and cross-clamp time between the mini sternotomy and the full sternotomy group, (mean difference (MD) 3.28 (95% CI − 3.69 to 10.25, $p = 0.3562$) and MD

Table 3 Post-operative outcomes of minimally invasive cohort

Characteristics	Number of studies reporting variable	*n*/*N* (%) or mean ± SD	Pooled prevalence (%)/pooled mean (95% CI)
Overall mortality	9/14	14/628 (2.2%)	2.23 (1.21–4.08)
In-hospital mortality	10/14	7/468 (1.5%)	1.18 (0.3–4.59)
Surgical site infection	10/14	34/871 (3.9%)	3.71 (2.32–5.91)
Conversion to open	7/14	32/552 (5.8%)	4.01 (1.70–9.18)
Post-op arrythmia	6/14	118/638 (18.5%)	12.15 (4.61–28.35)
Post of CHB requiring PPM	6/14	27/643 (4.2%)	4.2 (2.90–6.05)
Post-op stroke	6/14	26/661(3.9%)	3.93 (2.69–5.71)
Re-exploration for bleeding	9/14	42/799 (5.3%)	4.46 (2.43–8.06)
Post-op AKI requiring filtration	4/14	10/571 (1.75%)	1.75 (0.94–3.22)
Length of ICU stay (days)	12/14	2.59 ± 2.21	2.56 (1.78–3.34)
Length of hospital stay (days)	13/14	8.46 ± 3.38	8.43 (6.94–9.92)

ICU Intensive care unit, *AKI* Acute kidney injury, *CHB* Complete heart block, *PPM* Permanent pacemaker, n, total number of participants with characteristic of interest, N, total sample size of participants with which the presence or absence of characteristics is reported, % or mean, continuous variables reported as mean and categorical variables as percentages, *SD* standard deviation, *CI* confidence interval



POOLED PREVALENCE OF POST-OPERATIVE OUTCOMES IN THE MINIMALLY INVASIVE COHORT

Fig. 2 Forest plot showing the pooled prevalence of post-operative outcomes in the minimally invasive group

Table 4 Mini sternotomy vs full sternotomy outcomes

Characteristics	No. of studies	Mini sternotomy $n=269$	Full sternotomy $n=270$	Odds ratio/mean difference (95% CI)[a]	*P*-value [#]
Overall mortality	3/5	5/167 (3.0%)	4/175 (2.3%)	1.32 (0.34–5.16)	0.6891
In-hospital mortality	3/5	3/167 (1.8%)	4/175 (2.3%)	0.78 (0.17–3.62)	0.6545
Surgical site infection	4/5	6/197 (3.05%)	11/205 (5.4%)	0.58 (0.16–2.11)	0.4088
Post-op arrhythmia	2/5	33/122 (27.0%)	28/117 (23.9%)	0.68 (0.11–4.02)	0.6668
Post of CHB requiring PPM	3/5	10/194 (5.2%)	4/195 (2.1%)	2.50 (0.77–8.19)	0.1287
Post-op stroke	3/5	3/194 (1.55%)	3/195 (1.54%)	0.71 (0.28–1.85)	0.4892
Re-exploration for bleeding	3/5	5/167 (3.0%)	11/175 (6.3%)	0.46 (0.15–1.36)	0.1605
Post op AKI requiring filtration	2/5	3/122 (2.5%)	5/130 (3.8%)	0.42 (0.08–2.21)	0.3039
Length of ICU stay (days)	5/5	1.85 ± 0.90	2.22 ± 1.21	− 0.38 (− 0.78 to 0.02)	0.0611
Length of hospital stay (days)	5/5	8.19 ± 2.33	10.61 ± 4.18	− 2.21 (− 5.50 to 1.07)	0.1865
Operative time (mins)	3/5	178.39 ± 19.31	196.10 ± 25.19	− 17.0 (− 59.89 to 25.70)	0.4337
CPB time (mins)	5/5	102.31 ± 18.97	99.13 ± 15.47	3.28 (− 3.69 to 10.25)	0.3562
Cross-clamp time (mins)	5/5	72.71 ± 16.03	69.85 ± 11.65	2.07 (− 1.39 to 5.52)	0.2415

ICU Intensive care unit, *AKI* Acute kidney injury, *CHB* Complete heart block, *PPM* Permanent pacemaker, *CPB* Cardiopulmonary bypass

[a] Odds ratio for categorical variables and mean difference for numerical variables. [#] *P*-valve for random effects model

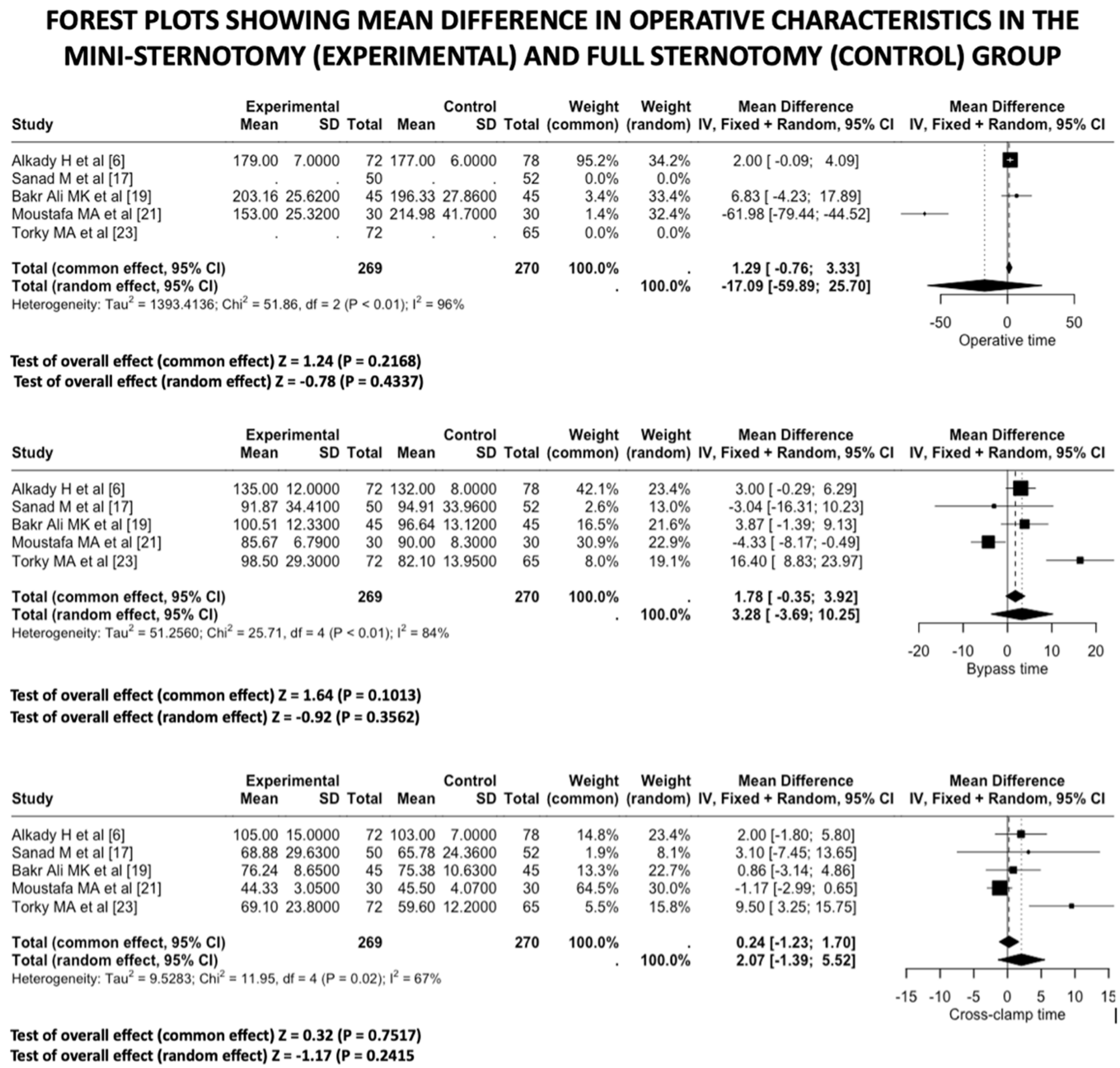


Fig. 3 Forest plot comparing operative characteristics between the mini sternotomy and full sternotomy group

2.07 (95% CI − 1.39 to 5.52, $p = 0.2415$), respectively (Fig. 3). Though the operative time of the mini sternotomy group was shorter, this difference (MD − 17: 95% CI − 59.89 to 25.70) was not found to be statistically significant ($p = 0.433$). The mean difference of overall mortality (MD 1.32: 95% CI 0.34–5.16, $p = 0.6891$) and in-hospital mortality (MD 0.78: 95% CI 0.17–3.62, $p = 0.6545$) between the two groups were also not statistically significant (Fig. 4). There was also no significant difference in other post-operative outcomes, such as surgical site infection, re-exploration for bleeding, and post-operative arrhythmia, between the two groups (Supplementary Fig. S3).

Discussion

Outcomes of MICS in Africa

In this review, we analysed the outcomes of MICS reported across countries in Africa. The meta-analysis of the reported outcomes produced a pooled in-hospital mortality prevalence of 1.18%, while the pooled overall mortality prevalence was 2.23%. A comprehensive review and meta-analysis by Modi et al. found no statistically significant difference in mortality between patients who

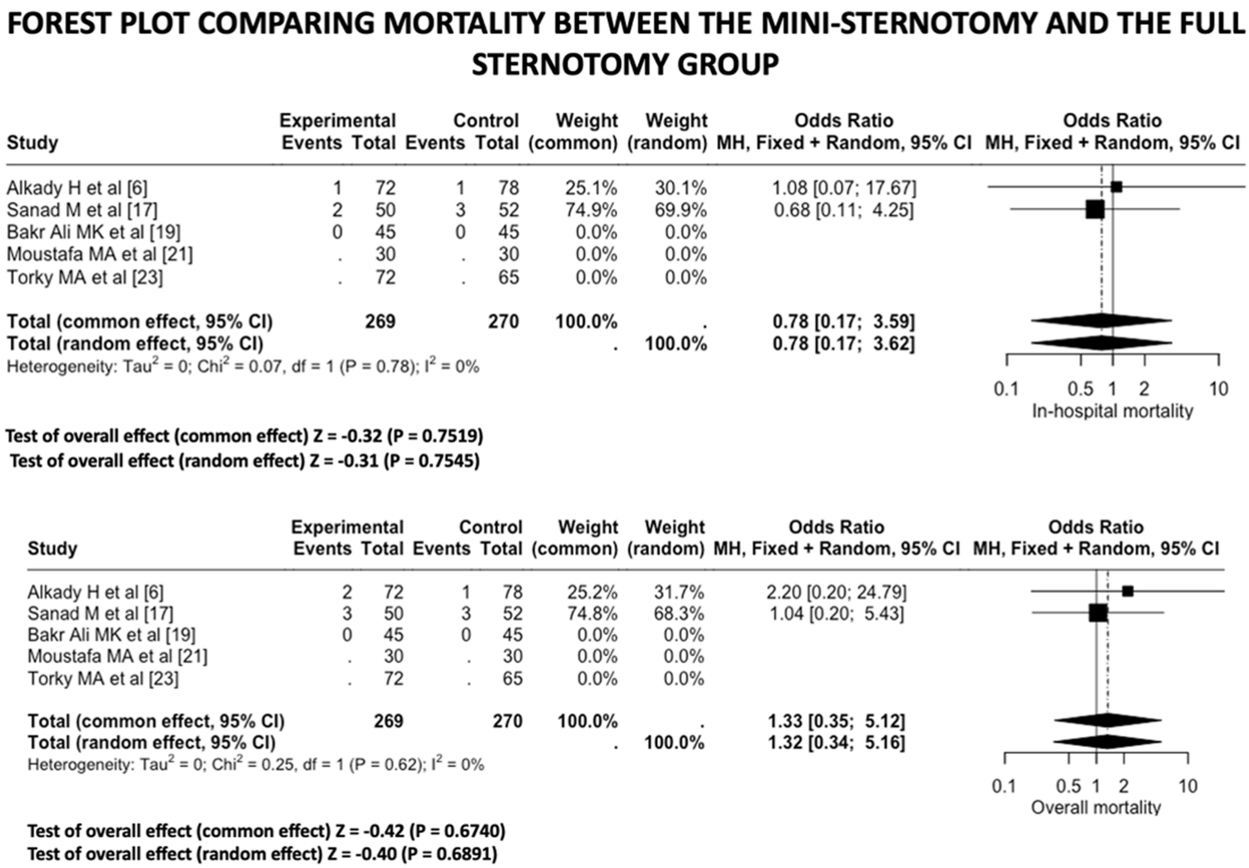


Fig. 4 Forest plot comparing mortality outcomes between the mini sternotomy and the full sternotomy group

underwent mitral valve surgery via either the MICS or open surgery. None of the 11 studies included in their review found a statistically significant difference in mortality [25]. This is like the result from our study that found no difference in both overall mortality and in-hospital mortality in patients who had mini sternotomy and full sternotomy.

In one of the US studies included in the review by Modi et al., the perioperative and overall mortality was found to be 0.2% and 3% in the minimally invasive mitral valve group [26]. Grossi et al. reported an in-hospital mortality of 3.7% in patients having either isolated mitral valve or aortic valve surgeries via the minimally invasive approach [27]. They also reported a 6-year overall mortality of 4.2% in the minimally invasive mitral valve surgery [28]. The higher overall mortality they reported compared to other studies could be attributed to the longer follow-up time of 6 years compared to the less than 5-year follow-up time seen in other prior mentioned studies. In our review, we report a pooled overall mortality of 2.23% which is slightly lower than those reported in these studies. This could possibly be explained by the fact that our review included patients who underwent minimally invasive coronary bypass, not only valvular surgeries. Though our meta-analysis which included 5 studies showed there was a shorter ICU stay in the mini sternotomy group compared to the full sternotomy group, this difference was not found to be statistically significant ($p=0.06$) (Supplementary Fig. S4).

Several empirical studies show that patients undergoing MICS experienced lower complication rates, shorter length of ICU stay, and hospital stays compared to those who had conventional open surgeries. In a systematic review by Dieberg et al., they reported on outcomes comparing all MICS vs open cardiac surgery [29]. Though they did not report on mortality outcomes, they reported statistically significant differences in length of ICU stay, cross-clamp time, CPB time, and operative time between the two groups. In their meta-analysis of length of ICU stay which included 6 prospective studies, they found that patients who underwent MICS compared to open surgeries had statistically significantly shorter ICU stay [29]. In contrast, in our study, this was not found to be statistically significant. This could be because our study included both retrospective and prospective studies, while the review by Dieberg et al. only included prospective studies.

Dieberg et al. reported longer cross-clamp time, bypass time, and operative time in the minimally invasive cardiac surgery patients [29]. Grossi et al. reported a mean cross-clamp and cardiopulmonary bypass times of 92 min and 127 min, respectively [27]. These results can be seen to be comparable to our study which showed similar average cross-clamp time and cardiopulmonary bypass times of 81.5 and 133 min, respectively. Cohn et al., in their study, demonstrated a significant decrease in post-operative complications, including post-operative bleeding and cerebral vascular accidents [30].

Limitations to the widespread use of MICS in Africa

Although minimally invasive cardiac surgery has gained widespread acceptance worldwide, there is limited documentation regarding its prevalence and utilisation in Africa. The potential for MICS to emerge significantly in Africa is greater than in its current state.

Cost of MICS

The economic evaluation of implementing MICS across the African continent is a topic of paramount importance. The available literature regarding MICS generally lacks specific information on the costs associated with these procedures. However, numerous publications from other regions, particularly resource-rich areas, have provided insights into the cost of performing MICS. Despite the technical complexity involved in MICS, it has been documented that it is generally less expensive than standard open sternotomy cardiac surgeries.

A study conducted by Arom et al. evaluated the financial and clinical appropriateness of coronary artery bypass grafting by comparing minimally invasive direct coronary artery bypass (MIDCAB) and full sternotomy off-pump to the conventional on-pump coronary artery bypass approach [31]. The study found that the MIDCAB approach resulted in cost savings for acute episodes of care when compared to the conventional approach. The cost analysis considered all hospital expenses, including direct and indirect costs, and fixed and variable costs, and results showed that intraoperative expenses were significantly lower for MIDCAB [31].

Another institutional study by Teman et al., comparing the costs and outcomes of minimally invasive versus open coronary surgery, found that MICAB resulted in cost savings of over 20%, with expenses totalling $27,906 compared to $35,011 for the open approach [32].

Though MICS presents numerous advantages, such as mitigated surgical trauma, expedited recovery, and reduced hospitalisation duration, the crucial aspect of cost-effectiveness within the African milieu remains a significant area of consideration [33, 34]. Funding and resource availability in the African context remain a limiting factor. The economic scrutiny of MICS in Africa necessitates a multi-faceted approach. To be considered is the initial monetary outlay for the establishment of MICS facilities, the steep costs of purchasing the specialised equipment and instruments, the overall financial implications of performing MICS, the enduring continuing costs associated with the upkeep and maintenance of facilities and equipment, and the supplementary cost of educating and training surgeons and other healthcare providers in effectively and proficiently delivering MICS. Though the cost of MICS surgeries may fluctuate based on the intricacy of the operation, the exact procedure undertaken, and the specific healthcare establishment, the high capital required to establish a MICS programme could serve as a limiting factor to the widespread adoption of MICS across Africa.

Lack of availability of CT surgeons in Africa

Across Africa, the demand for cardiac surgery services is higher than its supply. A shortage of expertise in MICS across Africa exacerbates the challenge. The study by Yankah et al. reported that there were only 933 cardiothoracic surgeons (CS) listed by CTSNet in Africa, indicating an average of one surgeon per 1.3 million individuals. In North Africa, this ratio was three surgeons per 1 million people, whereas in sub-Saharan Africa, it was one surgeon per 3.3 million individuals [35]. Excluding South Africa, this figure worsens to 1 in every 39 million individuals [35]. Another study reported that across all of Africa, there is only one surgeon to 4 million patients [10]. With this scarcity of cardiac surgeons to meet the demand of cardiac surgery in the continent, it is not surprising that MICS across the continent has not been well established. Without enough skilled practitioners, the potential benefits of minimally invasive approaches cannot be fully realised, leaving many patients without access to these advanced surgical options [10].

Also, the challenge of the prolonged learning curve associated with MICS can be attributed to its lack of widespread use in Africa. Holzhey et al. in their study reported that the acquisition of proficiency in performing minimally invasive mitral valve surgery typically necessitates a substantial number of procedures, ranging from 75 to 125, to surmount the learning curve, based on data from a high-volume centre [36]. Edwin et al. bring to light the imperative need for the investment in the training and pedagogy of cardiac surgeons in MICS techniques [37]. Cardiothoracic surgery training in Africa is also limited in several countries. Forcillo et al. in their study reported that most of the cardiac surgeons in Namibia, Uganda, and Zambia were trained abroad [38]. By broadening the spectrum of skilled professionals, a larger number of centres will be able to offer MICS, thereby boosting the accessibility of these procedures.

Lack of sufficiently equipped cardiac centres in Africa

In addition to the lack of personnel, there is also a lack of sufficiently equipped cardiac centres to meet the high demand of cardiac surgery in the continent. While efforts are being made to make cardiac surgery more accessible in African countries, there remains a substantial gap between the number of centres and the population [38]. The scarcity of cardiac surgery facilities in the region exacerbates the difficulty of carrying out MICS in Africa.

It has been reported that there are only 22 cardiothoracic centres in sub-Saharan Africa [35, 39], though this figure might be grossly inadequate, as there is a report of 13 cardiac surgery centres in Nigeria [40] and 48 centres in South Africa [41, 42]. Information from the Nigeria Heart Registry website shows that in the last 20 years (2004–2024), there are 26 centres in Nigeria which perform cardiac surgeries [43]. The report showed that in 2004, there were only 4 cardiac surgeries performed across the country. This number has increased considerably over the years, with 284 cardiac surgery procedures performed across Nigeria in 2023 [43]. Despite this increase, the burden and demand for cardiac surgery still exponentially outweigh the supply in the country.

In a recent systematic review that reported on cardiac surgery publication in Africa, it was reported that 26 out of the 54 African countries had studies published on cardiac surgery [41]. Of these 26 countries, over half of the studies included were from only four countries which include South Africa, Tunisia, Egypt, and Kenya [41]. In a review on coronary artery bypass surgery in Africa, only four countries, Algeria, Egypt, Nigeria, and South Africa, were included in the review [44]. However, a more recently published study by Effiom et al. reported about 154 cardiac centres across Africa [45].

Despite efforts by certain African nations to develop resilient cardiac programmes at regional levels, there remains a dearth of evidence regarding the capability of these centres to offer MICS procedures. In Nigeria, the lack of personnel and resources might have served as limitations to the commencement of MICS over the years, as a news report recently announced that the very first MICS in Nigeria was only done in August 2023 in a private facility [46]. The research by Zilla et al. underscores the urgency for an amplified allocation of resources and enhanced access to cutting-edge surgical equipment. The absence of the necessary resources and equipment makes it an uphill task to carry out MICS procedures effectively and without compromising on safety [47]. In many African countries, surgeries are often cancelled for various reasons, such as power outages, water and sanitation issues, lack of blood products, human resources, or lack of surgical materials and prostheses. Hence, although MICS has many benefits, their affordability and availability in the African settings are influenced by low-resource healthcare systems.

Recommendations

Considering these challenges, there is an urgent need to overcome the barriers hindering the adoption and advancement of MICS in Africa. Primarily, it is essential to channel investments into the training and pedagogy of cardiothoracic surgeons in MICS techniques. This goal can be brought to fruition through alliances with international organisations and synergies between healthcare institutions. By offering specialised training programmes, a larger number of surgeons can gain the necessary acumen to carry out MICS procedures efficiently.

Secondly, the increased allocation of resources and enhanced access to state-of-the-art surgical equipment are paramount to buttress the execution of MICS in Africa. Despite the potential initial financial strain, the long-term economic advantages of MICS should serve as a positive factor to encourage their establishment. Factors such as shortened hospital stay, enhanced patient outcomes, and swift recovery can significantly lessen overall costs on healthcare systems. A comprehensive economic appraisal can aid policymakers and healthcare providers in making informed decisions concerning the incorporation and application of MICS across Africa. Governments and healthcare organisations should prioritise the allocation of funds to healthcare to ensure that hospitals and specialised centres are resourced adequately to perform MICS procedures. Partnerships with medical equipment manufacturers could also facilitate access to the latest technology.

Lastly, fostering collaboration between international organisations, governments, and local healthcare institutions is vital to catalyse knowledge sharing and provide opportunities for training and capacity building. Utilising the expertise and resources of diverse stakeholders, the barriers to executing MICS in Africa can be surmounted more effectively. This collaboration could also pave the way for the establishment of guidelines and standards for MICS procedures in the African context.

Limitations of the study

We performed an extensive search to capture reported studies on outcomes of MICS in Africa, and these produced very limited studies to be included in our review. There is a slight probability that all research papers were not captured; however, it is more probable that some centres undergoing MICS in Africa have not published their results. This would therefore lead to a form of publication bias. Majority of the included studies were carried out in North Africa, especially Egypt. This could affect the generalisability of the result, as it might not be representative of other regions of Africa.

We also excluded studies with full text not available in English. In excluding these papers, we might have omitted important papers in regions of Africa that are non-English speaking. In addition, included papers were mostly observational studies with only a few countries in Africa included in the review. The lack of randomised control trials in the included studies provides a lesser level of evidence. This could not be avoided as we performed an extensive literature search which did not yield any randomised studies.

Conclusions

The pooled mortality outcomes of MICS reported in our study were comparable to those gotten from studies in other regions. Though there was a lack of sufficient data published on the outcome of MICS in Africa, this might not translate to mean these procedures are not practised in some of the cardiac centres in Africa. There are several limitations to the practice of MICS in Africa which include inadequate resources and infrastructure, insufficient funding, and limited number of CT surgeons trained in MICS, to name a few. It is important that the government in African countries take steps towards funding MICS programmes and also collaborate with international organisations for the training of cardiothoracic surgeons.

Abbreviations

CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
CVDs	Cardiovascular diseases
ICU	Intensive care unit
LVEF	Left ventricular ejection fraction
MD	Mean difference
MICS	Minimally invasive cardiac surgery
MIDCAB	Minimally invasive direct coronary artery bypass
NYHA	New York Heart Association
PRISMA	Preferred Reporting Items for Systematic Review and Meta-analysis

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43057-024-00134-0.

Additional file 1: Table S1. Search Strategy for Database Search. Table S2. Newcastle-Ottawa scale for assessing quality of the studies included. Figure S3. Forest plots showing incidence post-operative outcomes in the mini sternotomy (experimental) and full sternotomy (control) group. Figure S4. Forest plots showing difference length of ICU and hospital stay in the mini sternotomy (experimental) and full sternotomy (control) group.

Acknowledgements

Not applicable

Authors' contributions

OA, BA, MO, OO, SF, PA, RE, and FA were involved in the conceptualisation and design of the research, article screening, data interpretation, and manuscript writing. BO was involved in conceptualisation and supervision of the research and the review and editing of the manuscript draft. All authors read and approved the final manuscript.

Funding

No funding to declare.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable as no access to personalised patient information.

Competing interests

The authors declare that they have no competing interests.

Received: 11 June 2024 Accepted: 26 July 2024
Published online: 02 August 2024

References

1. Mack MJ (2006) Minimally invasive cardiac surgery. Surg Endosc Suppl 2:S488-492
2. Ilcheva L, Risteski P, Tudorache I et al (2023) Beyond conventional operations: embracing the era of contemporary minimally invasive cardiac surgery. J Clin Med 12(23):7210
3. Holubec T, Dahle G, Bonaros N. (2023) Editorial: minimally invasive cardiac surgery: state of the art and current challenges. Frontiers in Cardiovascular Medicine. 10. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10565476/
4. Iribarne A, Easterwood R, Chan EYH et al (2011) The golden age of minimally invasive cardiothoracic surgery: current and future perspectives. Future Cardiol 7(3):333–346
5. Doenst T, Diab M, Sponholz C et al (2017) The opportunities and limitations of minimally invasive cardiac surgery. Dtsch Arztebl Int 114(46):777–784
6. Alkady H, Abouramadan S (2022) A simple approach for minimally invasive combined aortic and mitral valve surgery. Thorac Cardiovasc Surg 70(2):120–125
7. Gouda HN, Charlson F, Sorsdahl K, Ahmadzada S, Ferrari AJ, Erskine H, Leung J, Santamauro D, Lund C, Aminde LN, Mayosi BM, Kengne AP, Harris M, Achoki T, Wiysonge CS, Stein DJ, Whiteford H (2019) Burden of non-communicable diseases in sub-Saharan Africa, 1990–2017: results from the Global Burden of Disease Study 2017. Lancet Glob Health 7(10):e1375–e1387
8. Minja NW, Nakagaayi D, Aliku T et al (2022) Cardiovascular diseases in Africa in the twenty-first century: gaps and priorities going forward. Front Cardiovasc Med 10(9):1008335
9. willdate. (2024) Challenges establishing minimally invasive cardiac surgery in the developing world. Cardiovascular News. Available from: https://cardiovascularnews.com/challenges-establishing-minimally-invasive-cardiac-surgery-in-the-developing-world/
10. Awuah WA, Adebusoye FT, Wellington J et al (2023) A reflection of Africa's cardiac surgery capacity to manage congenital heart defects: a perspective. Ann Med Surg (Lond) 85(8):4174–4181

11. Attman WG, El Tahan S (1999) Minimally invasive closed mitral commissurotomy. Tex Heart Inst J 26(4):269–274
12. Ussiri EV, Nyawawa ETM, Wandwi WBC, et al (2011). Closed mitral valvotomy-a life saving procedure in facility deprived countries: experience at Muhimbili National Hospital, Tanzania. East Central Afr J Surg. 16(1). Available from: https://www.ajol.info/index.php/ecajs/article/view/72491
13. Ouzzani M, Hammady H, Fedorowicz Z et al (2016) Rayyan—a web and mobile app for systematic reviews. Syst Rev 5(1):210
14. Harris DG, Coetzee AR, Augustyn JT et al (2009) Repeat surgery for coronary artery bypass grafting: the role of the left thoracotomy approach. Heart Surg Forum 12(3):E163-167
15. Zallé I, Son M, El-Alaoui M, et al (2021) Minimally invasive and full sternotomy in aortic valve replacement: a comparative early operative outcome. Pan Afr Med J 40:68
16. Abd Al Jaward M, F M (2022). Measurement of health-related quality of life post aortic valve replacement via minimally invasive incisions. J Cardiothorac Surg 17(1):208
17. Sanad M, Beshir H (2020) Minimally invasive aortic valve replacement with central cannulation: a cost-benefit analysis in a developing country. Cardiothorac Surg 28(1):9
18. Mourad F, Abd Al Jawad M (2021) Mini sternotomy and mini thoracotomy for aortic valve replacement: is there a difference? Heart Surg Forum 24(5):E855–E859
19. Bakr Ali MK, Abdelaal MM, Elfeky WM, et al (2023). Mini-sternotomy versus conventional sternotomy in aortic valve replacement surgery: a comparative study. JPMA J Pak Med Assoc. 73(Suppl 4)(4):S56–60
20. El-Fiky MM, El-Sayegh T, El-Beishry AS et al (2000) Limited right anterolateral thoracotomy for mitral valve surgery. Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg 17(6):710–713
21. Moustafa MA, Abdelsamad AA, Zakaria G, et al (2007). Minimal vs median sternotomy for aortic valve replacement. Asian Cardiovasc Thorac Ann. https://doi.org/10.1177/021849230701500605
22. El Midany AAH, Doghish AA (2019) Ministernotomy approach for modified Blalock-Taussig shunts in neonates: a feasibility study. Cardiothorac Surg 27(1):1
23. Torky MA, Arafat AA, Fawzy HF, et al (2021) J-ministernotomy for aortic valve replacement: a retrospective cohort study. Cardiothorac Surg 12;29(1):16.
24. El Adel M, Nady MA, Amin A et al (2022) A randomized controlled trial (PAMI trial) on our new trend periareolar minimally invasive (PAMI) technique versus inframammary approach for minimally invasive cardiac surgery. Cardiothorac Surg 30(1):29
25. Modi P, Hassan A, Chitwood WR (2008) Minimally invasive mitral valve surgery: a systematic review and meta-analysis. Eur J Cardiothorac Surg 34(5):943–952
26. Mihaljevic T, Cohn LH, Unic D et al (2004) One thousand minimally invasive valve operations: early and late results. Ann Surg. 240(3):529–34 (discussion 534)
27. Grossi EA, Galloway AC, Ribakove GH et al (2001) Impact of minimally invasive valvular heart surgery: a case-control study. Ann Thorac Surg 71(3):807–810
28. Grossi EA, Galloway AC, LaPietra A et al (2002) Minimally invasive mitral valve surgery: a 6-year experience with 714 patients. Ann Thorac Surg. 74(3):660–3 (discussion 663–664)
29. Dieberg G, Smart NA, King N (2016) Minimally invasive cardiac surgery: a systematic review and meta-analysis. Int J Cardiol 223:554–560
30. Cohn LH, Adams DH, Couper GS et al (1997) Minimally invasive cardiac valve surgery improves patient satisfaction while reducing costs of cardiac valve replacement and repair. Ann Surg. 226(4):421–6 (discussion 427–428)
31. Arom KV, Emery RW, Flavin TF et al (1999) Cost-effectiveness of minimally invasive coronary artery bypass surgery. Ann Thorac Surg 68(4):1562–1566
32. Teman NR, Hawkins RB, Charles EJ et al (2021) Ann Thorac Surg. 111(5):1478–84
33. Hawkins RB, Mehaffey JH, Mullen MG, Investigators for the Virginia Cardiac Services Quality Initiative et al (2018) A propensity matched analysis of robotic, minimally invasive, and conventional mitral valve surgery. Heart. 104(23):1970–5
34. Downs EA, Johnston LE, LaPar DJ, I, (2016) Minimally invasive mitral valve surgery provides excellent outcomes without increased cost: a multi-institutional analysis. Ann Thorac Surg 102(1):14–21
35. Yankah C, Fynn-Thompson F, Antunes M et al (2014) Cardiac surgery capacity in sub- saharan Africa: quo vadis? Thorac Cardiovasc Surg 62(5):393–401
36. Holzhey DM, Seeburger J, Misfeld M et al (2013) Learning minimally invasive mitral valve surgery. Circulation 128(5):483–491
37. Edwin F, Tettey M, Aniteye E et al (2011) The development of cardiac surgery in West Africa–the case of Ghana. Pan Afr Med J 9:15
38. Forcillo J, Watkins DA, Brooks A, contributors from Namibia, Zambia, and Uganda et al (2019) Making cardiac surgery feasible in African countries: experience from Namibia, Uganda, and Zambia. J Thorac Cardiovasc Surg. 158(5):1384–93
39. Ozkan J (2018) A snapshot of cardiology in Africa. Eur Heart J 39(23):2128–2129
40. iwosanlh (2023). The heart of Nigeria's healthcare crisis: how cardiovascular disease is straining the system. Iwosan Lagoon Hospitals. Available from: https://www.lagoonhospitals.com/updates/the-heart-of-nigerias-healthcare-crisis-how-cardiovascular-disease-is-straining-the-system/
41. Lin Y, Till BM, Yi S et al (2020) Cardiac surgery publications in Africa over the last 20 years: a literature review. S Afr J Sci 116(1–2):1–6
42. Kahamba N (2021). Outcomes of cardiac surgery at the Aga Khan University Hospital Nairobi – a one year review. Theses & Dissertations. Available from: https://ecommons.aku.edu/theses_dissertations/1971
43. Nigeria Heart Registry (2024) Search by procedure/operation/diagnosis | NigeriaHeartRegistry. Available from: https://www.nigeriaheartregistry.com/which-operation-which-centre
44. Akintoye OO, Fasina OP, Adiat TS et al (2023) Outcomes of coronary artery bypass graft surgery in Africa: a systematic review and meta-analysis. Cureus 15(10):e47541
45. Effiom VB, Michael AJ, Ahmed FK, et al (2024). Cardiothoracic surgery training in Africa: history and developments. JTCVS Open. Available from: https://www.sciencedirect.com/science/article/pii/S2666273624000639
46. Nwafor. (2023) Tristate Hospital pioneers minimal invasive heart surgery in Nigeria. Vanguard News. Available from: https://www.vanguardngr.com/2023/08/tristate-hospital-pioneers-minimal-invasive-heart-surgery-in-nigeria/
47. Zilla P, Bolman RM, Yacoub MH et al (2018) The Cape Town declaration on access to cardiac surgery in the developing world. Cardiovasc J Afr 29(4):256–259

Publisher's Note