Percutaneous coronary interventions in Sudan: insights from severely influenced conflict zone

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Background **Sudan is among the few countries in sub-Saharan Africa that offers free thrombolytic therapy and complimentary access to catheterization laboratories for its patients. This study examines the patterns of percutaneous coronary interventions (PCIs) conducted within 1 year during the Sudan war of 2023–2024 in low-resource regions within the conflict zone.**

Methods **We conducted a retrospective descriptive analysis at El-Obeid International Hospital in North Kordofan State, Sudan, from April 2023 to 2024. We have systematically collected data pertaining to patients who underwent the procedure during the specified period.**

Results **We investigated 100 patients who underwent PCIs. We performed PCIs in 80% of cases for patients with acute coronary syndrome and 20% for those with chronic coronary syndrome. All patients involved in the procedures used drug-eluting stents. Males constituted 64% of the total, while females accounted for the remaining 36%. The most common age groups are 60–69 and 50–59, with incidence rates of 31 and 30%, respectively. Approximately 51% of the participants resided in rural areas, while the remaining 49% were from urban locations. About 32% of the patients held employment, while 24% were unemployed. In 92% of cases, the vascular access was femoral, while the remaining 8% utilized radial access.**

Conclusion **It is feasible to establish and maintain catheterization laboratory services despite the challenges posed by war and the associated risks to personal safety. We must enhance healthcare policies, regional networks, and training to improve access to thrombolytic therapy within the necessary timeframe. Certain centers in Sudan can safely conduct primary PCI. *Cardiovasc Endocrinol Metab* 14: 1–7 Copyright © 2025 The Author(s). Published by Wolters Kluwer Health, Inc.**

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Introduction

Cardiovascular disease (CVD) represents a significant global public health issue, with China reporting the highest mortality rates associated with this condition. The age-standardized CVD mortality rates in North Africa and the Middle East ranged from 134.2 to 600.2 per 100 000 in 2021, which is higher than the rates reported in Western Europe for the same year, which ranged from 82.2 to 214.6 per 100 000 [1]. More and more people with coronary artery disease are undergoing percutaneous coronary intervention (PCI) procedures. Meanwhile, an increasing number of studies are examining the application of PCI strategies for prognostic assessment and cardiac rehabilitation [2]. The advancements in drug-eluting stents (DES) and intravascular imaging modalities, including intravascular ultrasonography and optical coherence tomography, contribute to improved cardiovascular outcomes in patients undergoing PCI [3]. The impact of intravascular ultrasound guidance on the outcomes of Xience Prime stents in long lesions trial (IVUS-XPL), which included 1400 patients, demonstrated a sustained reduction in major cardiovascular adverse events over 5 years with the use of intravascular ultrasound in patients with long lesions [4]. However, the absolute effects of these intravascular images appear to be influenced by additional factors, including the patient's baseline clinical profiles, risk factors, and the complexity and severity of coronary artery disease [5]. Acute myocardial infarction, with or without obstructive coronary artery disease as observed in angiography, affects over 750 000 individuals annually in the USA [6]. The occurrence of myocardial infarction with nonobstructive coronary artery disease, characterized by less than 50% stenosis in all major epicardial coronary vessels, is noted in 6% of all acute myocardial infarction cases, with a higher prevalence among

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younger patients and women [7,8]. Sudan is situated in northeastern Africa, with a population of 41.8 million before the 2023–2024 conflict and a life expectancy of 65 years [9]. The area is approximately 1.8 million square kilometers, roughly twice that of Germany and France combined. The inaugural cardiac catheterization laboratory (Cath lab) in Sudan was established in 1976 at Alshab Teaching Hospital, the principal tertiary hospital in the nation, where the first instances of left and right heart catheterization were conducted that same year [10]. Before the 2023–2024 Sudan conflict, the country had 18 catheterization laboratories, 13 of which were situated in the capital, Khartoum. The 18 catheterization laboratories conducted PCIs and pacemaker implantation as routine daily practices. Because of extensive damage to the health system caused by the war across the country, there are currently only four operational catheterization laboratories, all located outside the capital, Khartoum. Our center is located in the conflict zone. Patients were received from across the country despite the limited availability of operational supplies, insufficient trained Cath lab personnel, and financial constraints. This study examines the patterns of PCIs conducted within 1 year during the Sudan conflict.

Materials and methods

This study is a retrospective descriptive study undertaken at El-Obeid International Hospital (Aldaman), located in North Kordofan State, Sudan, spanning from April 2023 to 2024. Data pertaining to patients who received PCI at the El-Obeid International Hospital Catheterization Laboratory from 15 April 2023 to 15 April 2024, were meticulously gathered. All pertinent information regarding the patients was obtained from the hospital.

Before the intervention, all patients received the following therapies: dual antiplatelet therapy (DAPT) consists of – aspirin 300 mg (loading dose), followed by a maintenance dose of 100 mg daily – clopidogrel 600 mg (loading dose), followed by a maintenance dose of 75 mg daily. All patients received high-intensity statins, specifically atorvastatin at a dosage of 80 mg daily and rosuvastatin at 20 mg daily. All patients received unfractionated heparin at a dosage of 70–100 IU/kg during the procedure.

People who have type 2 diabetes mellitus (T2DM) were all given sodium-glucose cotransporter 2 inhibitor (SGL2I) in the form of dapagliflozin 10 mg every day, along with metformin at a dose of 1–2 g every day. Some patients received insulin glargine, vildagliptin, and sitagliptin to enhance metabolic control.

Statistical analysis

We organized all patient data into a data sheet before entering it into the Statistical Package for the Social Sciences (SPSS) version 24 (Chicago, Illinois, USA). We examined the data to ascertain frequencies, percentages, and cross-tabulations.

Results

Demographic characteristics of the patients

We studied 100 patients who underwent PCI, ranging in age from 27 to 89 years, with a mean age of 57.43 years (SD = 12.03).

Sixty-four out of 100 (64%) were males, and 36 out of 100 (36%) were females. Fifty-one out of 100 (51%) patients resided in rural areas, whereas 49 out of 100 (49%) patients resided in urban areas.

The predominant age group is 60–69, followed by 50–59, less than 50, and greater than or equal to 70, with incidence rates of 31, 30, 22, and 17%, respectively.

The majority of patients were illiterate, followed by those with a university education, basic education, and secondary education, comprising 60, 25, 8, 4, and 3%, respectively.

The majority of patients were laborers, followed by unemployed individuals, businessmen, teachers, armed forces personnel, retirees, and doctors. Farmers and employed individuals had equal representation, with the following distribution: 32, 24, 8, 7, 4, 3, 2, 1, and 11%, respectively.

Nine out of 100 (9%) patients were single, while the majority (89%) were married.

Types of percutaneous coronary intervention and its association with demographic features

The majority of patients who received percutaneous coronary procedures were Primary percutaneous coronary intervention (PPCI), followed by PCI for patients with chronic coronary syndrome (CCS), PCI for non-ST segment elevation acute coronary syndrome (NSTE-ACS), and pharmacoinvasive approaches, which represented 50, 27, 20, and 3%, respectively, as shown in Fig. 1.

In patients undergoing PPCI, males constituted 35 out of 50 (70%), whereas females accounted for 15 out of 50 (30%). In the CCS group, the male representation was 17 out of 27 (63%), whereas females accounted for 10 out of 27 (37%). In patients with NSTE-ACS, males constituted nine out of 20 (45%), while females accounted for 11 out of 20 (55%). Notably, all patients (three out of three, or 100%) in the pharmacoinvasive strategy (PIS) were males.

The predominant age group in the PPCI cohort is 50–59 years, followed by 60–69 years, with individuals aged less than or equal to 50 and greater than or equal to 70 comprising 34, 30, 24, and 12%, respectively. In the CCS group, the predominant age ranges are less than or equal to 50 and greater than or equal to 70, followed by 50–59 and 60–69, which account for 29.6, 25.9, and 14.8%, respectively.

Fig. 1

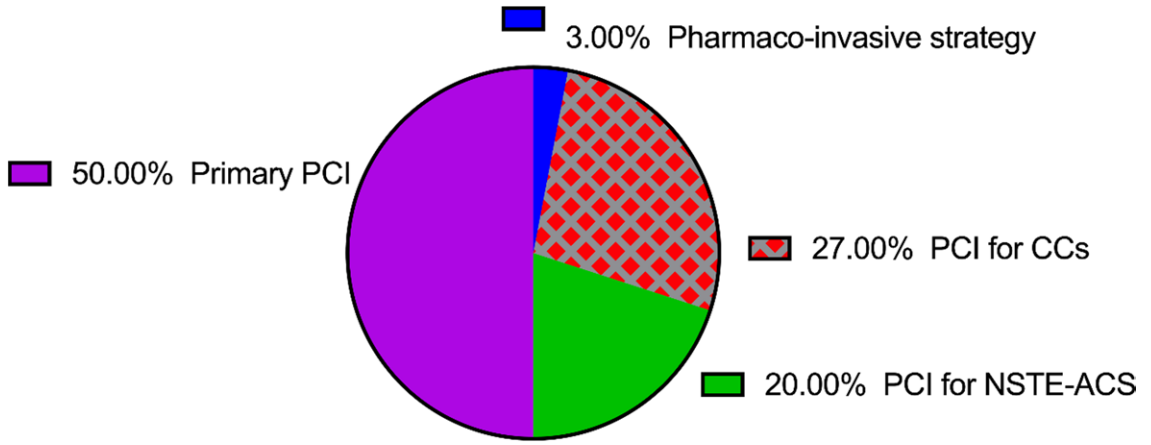


Illustration of various types of PCI. CCS, chronic coronary syndrome; NSTE-ACS, non-ST segment elevation acute coronary syndrome; PCI, percutaneous coronary intervention.

Table 1 The distribution of the patients according to the types of percutaneous coronary intervention, sex, age, residence, and vascular access.

Variable	Primary PCI	PIS	PCI for CCS	PCI for NSTE-ACS	Total
Sex					
Male	35	3	17	9	64
Female	15	0	10	11	36
Total	50	3	27	20	100
Age (years)					
≤50	12	0	8	2	22
50–59	17	3	7	3	30
60–69	15	0	4	12	31
≥70	6	0	8	3	17
Total	50	3	27	20	100
Residence					
Rural	26	1	13	11	51
Urban	24	2	14	9	49
Total	50	3	27	20	100
Vascular access					
Femoral	47	2	25	18	92
Radial	3	1	2	2	8
Total	50	3	27	20	100

CCS, chronic coronary syndrome; NSTE-ACS, non-ST segment elevation acute coronary syndrome; PCI, percutaneous coronary intervention; PIS, pharmacoinvasive strategy; PPCI, primary percutaneous coronary interventions.

In the NSTE-ACS group, the age range with the most people is 60–69, followed by 50–59 and greater than or equal to 70, which are evenly spread out. All patients (100%) in the PIS were between the ages of 50 and 59 years.

In the PPCI group, 26 out of 50 (52%) participants resided in rural areas, whereas 24 out of 50 (48%) participants were in urban locations. In the CCS group, 14 out of 27 (52%) participants were from urban areas, while 13 out of 27 (48%) participants were from rural areas. In the NSTE-ACS group, 11 out of 20 (55%) participants were from rural areas, whereas nine out of 27 (45%) participants were from urban areas. In the PIS, 66.66% were urban, while 33.33% were rural. Femoral access constituted the predominant method of access in our interventions, accounting for 92%, as illustrated in Table 1 and Fig. 2.

In this series of patients, 35% were people with diabetes and 38% were with hypertension.

Outcomes

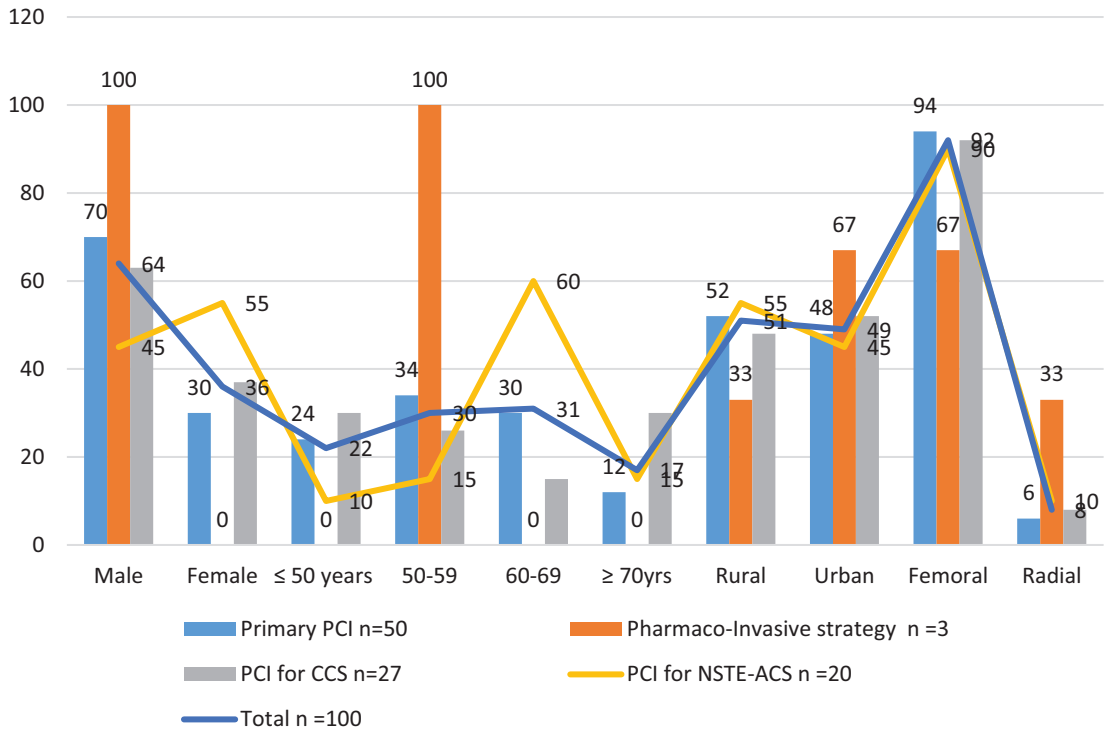
A total of 97 out of 100 (97%) patients were discharged from the hospital after improvement, while three out of 100 (3%) patients died in the hospital; Table 2 and Fig. 3 demonstrate this.

Discussion

Global recognition has acknowledged the significant impact of the 2023 Sudan war on the health system and patient management. Cardiac patients experience significant challenges, particularly those requiring urgent cardiovascular interventions, as only three of the 18 Cath lab centers in the country are located outside the conflict zone and are able to continue operations. These three centers are in Sheindy and Atbara cities in the River Nile state, and one in Marawi city in the Northern state. In April 2018, the National Cardiac Center initiated a program to comprehensively support all coronary interventions, along with specific valve interventions and pediatric congenital interventions. Sudan is among the few countries in sub-Saharan Africa that offers free thrombolytic therapy and complimentary access to Cath lab services for its patients [10].

This survey found that rural patients marginally outnumbered urban ones. Patient demographics and geography affect ST-elevation myocardial infarction (STEMI) management worldwide. Patients with rural STEMI risk delays in medical attention because of distance and a lack of ambulance and healthcare resources. STEMI care paradigms must be improved to reduce rural-urban

Fig. 2



The distribution of patients based on the types of percutaneous coronary intervention, sex, age, residence, and vascular access. CCS, chronic coronary syndrome; NSTE-ACS, non-ST segment elevation acute coronary syndrome; PCI, percutaneous coronary intervention.

Table 2 The outcomes of percutaneous coronary interventions.

Variable	Males	Females	Total
Outcomes			
Improved and discharge	62	35	97
In-hospital death	2	1	3
Total	64	36	100

cardiovascular morbidity and mortality. Long distances and transfer times limit PPCI in rural locations, requiring better care models [11].

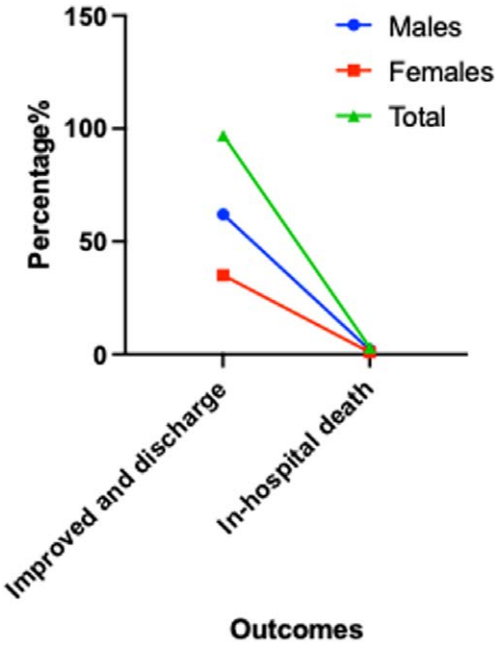
This study found that most patients were men. Many studies show gender differences in diagnostic and invasive therapeutic cardiac procedures. Women receiving primary PCI for STEMI have a greater risk of in-hospital mortality than men, with an age-adjusted odds ratio of 1.19 [95% confidence interval (CI): 1.06–1.33). They also have an age-adjusted odds ratio of 1.19 (95% CI: 1.16–1.29) for ischemic cardiac and cerebrovascular events such as mortality, myocardial infarction, and transient ischemic attack/stroke. Access-related problems were twice as common in women, independent of reason. Women receiving PCI for STEMI have a 20% higher age-adjusted risk of death and ischemic cardiac and cerebrovascular events, despite comparable technical success rates. More research is needed to determine why these differences exist [12].

The current study revealed that the majority of patients with ACS underwent PCI, using DES in all cases including primary PCI, PCI in NSTE-ACS, and three PCI after thrombolysis. PPCI is the standard treatment for people who have had an acute STEMI. It is the most effective way to restore blood flow and greatly improves the patient's prognosis. Despite advancements in revascularization, adverse cardiovascular events continue to occur [13].

Despite the challenges posed by limited resources and the ongoing conflict, the current study indicates an in-hospital mortality rate of approximately 3%, which is comparatively low when assessed against previous publications from sub-Saharan Africa and globally [13,14]. The in-hospital mortality rate for patients with STEMI is between 4 and 12%, with a 1-year mortality rate of approximately 10% [14]. In sub-Saharan Africa, the in-hospital mortality for patients with ACS varies significantly, ranging from 1.2 to 24.5%, influenced by the study populations and the type of revascularization procedure conducted [15]. Mortality rates at follow-up ranged from 7.8 to 43.3%.

In Sudan, a PPCI program has commenced at Alshaab Teaching Hospital, fully funded by the National Cardiac Center. This program serves patients who present in a timely manner and adhere to the hospital's local protocols. However, this service remains limited in availability at

Fig. 3



Depiction of the outcomes of percutaneous coronary interventions.

other centers, as our center is only working one at the hottest armed conflict zone. Because of our center's location in the conflict zone and the challenges posed by the war, our achievement of 100 PCI in a single year is significantly lower than our predisaster performance and that of other centers in the country. In a prospective cohort study at a tertiary hospital between November 2020 and February 2021, Hasabo *et al.* [16] reported 124 PCIs. The National Cardiac Centre adopted a PIS for managing patients with acute STEMI presenting within 12 h of chest pain onset. However, the current study revealed that only 3% of PCIs were performed on patients with STEMI who received thrombolysis because of late presentation (beyond 12 h), resulting in 50% of these patients undergoing PPCI.

After discussions with the cardiac surgeon, some thrombolyzed patients received referrals for surgery and medical therapy, resulting in their exclusion from the study. This significant finding falls short of the Sudan Heart Society's objective for patients with STEMI (thrombolysis for all). Despite advancements in thrombolysis, significant work remains in this region. Our center and local authorities must urgently establish local protocols and guidelines. Evidence from developed countries indicates that the implementation of such recommendations has improved practices and reduced mortality rates among patients with ACS in recent years [17]. Reliable ambulance services are essential for the timely transfer of patients and the administration of thrombolytic therapy. This necessitates the establishment of a focused training program for physicians and healthcare providers, alongside enhancements in the availability of local resources, particularly ECG machines and life-saving medications, including thrombolytic agents. We must also develop effective referral systems and a network of local and national catheterization laboratories. The current study exhibited a male predominance of 64%, aligning closely with previously reported figures from Sudan at 65.7% [16] and other global studies. In certain sub-Saharan countries, male predominance in primary PCI procedures reached 91.2% [18]. Sudan had the highest female representation at 43.1% [19], followed by Tanzania and Kenya at 40.1% [9,20,21]. In the present study, females constituted the majority of the NSTE-ACS group, accounting for 55% of the participants. The mean age of participants was 57.43 ± 12.03, comparable to previously published values (57.9 ± 10.4) in Sudan [16]. However, studies from certain sub-Saharan African regions reported lower mean ages in patients with STEMI who underwent PPCI (54.5 ± 10.5) [15,18].

Despite the presence of trained radial operators, most PCIs in the current study used femoral access. The adverse effects of the war have led to a shortage of radial sheaths and equipment necessary for the transradial approach, which accounts for this preference. Numerous publications suggest that transradial coronary angiography and PCI lead to superior clinical outcomes, specifically a reduced risk of bleeding and improved patient comfort compared with the transfemoral approach. The European Society of Cardiology has long advocated for a radial-first approach, as emphasized in the recent guidelines from the American College of Cardiology and the American Heart Association for coronary revascularization [22].

In this study, clopidogrel and aspirin were used as the standard DAPT because other P2Y12 inhibitors like ticagrelor and prasugrel were not available at our center. There was a big drop in major and minor bleeding, net adverse cardiovascular and cerebrovascular events, and all-cause mortality after short-term DAPT and then ticagrelor monotherapy for up to 12 months after DAPT [23].

The current guidelines advocate for DAPT for a duration of 6–12 months following PCI, while recent studies have evaluated the safety and effectiveness of reducing DAPT duration to 3 months or less. A brief duration of DAPT for less than or equal to 3 months is linked to a reduction in net adverse clinical events and bleeding when followed by monotherapy with a P2Y12 inhibitor, specifically ticagrelor, with no significant differences in other outcomes. Patients with ACS or CCS after PCI with a DES should be thought of as benefiting from this method [24].

Nonetheless, several patients in this series had T2DM and hypertension. Still, having both high blood pressure

and diabetes at the same time caused changes in a number of metabolic markers [25]. SGLT2 inhibitors, an innovative class of oral antidiabetic medications, have exhibited cardioprotective advantages and favorable metabolic outcomes in individuals with diabetes. SGLT2 inhibitors may decrease ventricular vulnerability to arrhythmias within 6 months of treatment in patients with diabetes. These medications seem to inhibit the advancement of both cardiovascular and renal illnesses in diabetic as well as nondiabetic human individuals [26].

Recent advances in pharmacology suggest single-pill combinations and strict blood pressure goals (<130/80 mmHg), pointing out the benefits of SGL2Is for certain comorbidities. Minimally invasive renal denervation is investigated for resistant hypertension, while telehealth and mobile apps improve patient engagement and adherence. This patient-centered, multimodal strategy improves blood pressure control, lowers the risk of heart disease, and treats hypertension in a wide range of groups [27].

Although the current study has offered significant insights and examined the circumstances of a subset of patients requiring critical medical attention, it is not without its limitations, such as its retrospective design and constrained sample size.

Conclusion

Establishing and maintaining PCIs during a crisis is feasible despite the challenges posed by the conflict. We should promote healthcare policies, regional networks, and training to improve access to thrombolytic therapy within the required timeframe. Select centers within Sudan can safely conduct primary PCI.

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Authorities at El-Obeid International Hospital granted permission to access the notified information.

The Human Research Ethics Committee at MRCC has approved the study's proposal. Approval Number: HREC0013/PMRCC.9/24.

Data regarding this study are available from the corresponding author.

Conflicts of interest

There are no conflicts of interest.

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