Demographic Predictors of Heparin Resistance in Patients Undergoing Cardiac Operations with Cardio Pulmonary Bypass in Adult Population

Original Article

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ABSTRACT

Background: Heparin allowed safe anticoagulation to be able to establish Bypass , hence the importance of fully understanding and predicting occurrence of heparin resistance.

Objective: To predict the impact of demographic factors among adult patients undergoing heart surgery with cardiopulmonary bypass on likelihood of developing Heparin resistance.

Methodology: For that we included in our study 219 selected patients who has done Cardiac surgery with cardio- pulmonary bypass, over a time period of 18 months all demographic factors were listed and analysed.

Results: Out of the 219 patients included in the study 16 patients were considered as heparin resistant and on analyzing demographic data of that group it showed significantly more men, smokers, old age and hypertension patients.

Conclusion: Old age, hypertension, smoking and male sex are significant risk factors to develop HR in cardiac surgery using cardio-pulmonary bypass.

Key Words: Adult cardiac surgery, activated clotting time, cardio-pulmonary bypass, COVID-19, heparin resistance, non heparin resistant.

Received: 13 March 2025, **Accepted:** 25 March 2025.

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ISSN: 2735-3540, Vol. 76, No. 2, June 2025.

INTRODUCTION

Discovery of CPB opened the door for a bloodless and immobile cardiac operative Field, starting a revolution in the world of cardiac surgery. In order to avoid thrombosis Heparin was used to solve the technical difficulty within the established bypass circuit, enabling safe anticoagulation to be instituted and then later on safely reversed at end of operation[1].

Heparin is considered a sulfated polysaccharide" By inactivating thrombin and activated factor X (factor Xa) via an antithrombin (AT)-dependent mechanism, it generates its primary anticoagulant impact. Numerous clinical settings employ heparin treatment. Since each patient has a different anticoagulant response to heparin, it is common practice to modify the dosage of heparin and use measurement of the activated thromboplastin time (APTT) to adjust its dose or by the activated clotting time (ACT) if high doses of heparin are used such as in cardiac surgery. Achieving target levels of anticoagulation within a short time frame is crucial for best surgical outcomes, considering the severity of the illnesses treated with heparin[2].

Sub therapeutic ACT levels can result from patient's diminished response to heparin also known as heparin resistance (HR). Insufficient anticoagulation can result in dramatic outcomes such as thromboembolic phenomena, excessive postoperative bleeding, and consumptive coagulopathy[3].

Due to the undetermined target ACT, a range of ACT targets, from 400 to 500 seconds, are employed in clinical practice for the start and maintenance of CPB. Because of this, several criteria have been applied in the literature to define heparin resistance[4].

When standard-of-care heparin fails to reach the goal ACT, there are now four major therapies to establish enough anticoagulation in cardiac operations[5].

DOI: 10.21608/ASMJ.2025.367914.1409

These consist of administering more heparin, supplementing with FFP or an AT concentrate (purified or recombinant), administering a different anticoagulant, or not administering any extra medication[6].

Most studies defined HR as (ACT less than 400 seconds 5 min after administration of 300 U/kg heparin)[7].

The exact mechanism of HR is unknown although some theories say high levels of heparin binding protein (they are considered acute phase reactants), decreased levels of antithrombin-III (i.e.nothing for heparin to bind to, high heparin clearance levels (eg. Having enlarged spleen in a liver pathology), or increased levels of Factor VIII.

AIM OF THE WORK

The main goal of our study was to determine whether demographic differences between adult patients undergoing cardiac surgery using CPB has any role in affecting there susceptibility of developing HR.

Type of the study

An analytical cross-sectional research conducted over 18 months with the primary goal of determining demographic predictors for heparin resistance in adult populationundergoing cardiac surgery using cardio-pulmonary bypass.

METHODOLOGY

This cross sectional study included 219 participants who were selected from the patients who underwent cardiac surgery either elective or emergency using cardio-pulmonary bypass on a time limit of 18 months. Participants in the research comprised adult patients > 18 years old of both sexes,. However, participants with known coagulation abnormalities, severe liver illness, renal failure, or cancer were excluded from the trial.

All patients were subjected to an informed consent, Demographic data, Complete history taking, complete physical examination, operation type, laboratory examination (with special emphasis on CBC, renal function, liver function and coagulation.

All patients were opened using median sternotomy with Aortic and caval or bicaval cannulation.

After receiving heparin medication before surgery, patients were assessed for heparin resistance. We started Cardiopulmonary bypass after confirming a sufficient ACT in either normothermia or mild hypothermia (34°C). To reach the desired ACT value, 400 seconds of heparinization with 300 IU kg-1 unfractionated heparin was used. A Hemochron 401 coagulation monitoring equipment (Technidyne Corp., Edison, NJ, USA) was utilized to measure ACT. After CPB was withdrawn, protamine sulphate was administered in a 1:1 ratio to reverse the original heparin dosage. A questionnaire was formatted to assess heparin resistance following heparin administration. The questionnaire includes possible predicted parameters such as demographics, pre, intraoperative, and post-operative variables.

We defined Heparin resistance using an ACT-based approach (ACT less than 400 seconds 5 min after infusing 300 U/kg heparin)

ETHICAL CONSIDERATION

Approval from Faculty of Medicine Ain Shams University ethical committee was obtained (No. FWA000017585; Date: 25/10/2023). Informed consent was taken from every participant after explaining the purpose of the study. All research participants received an explanation of the following basic guidelines: participating in this study was with absolutely no charge and was done voluntarily.

Statistical Analysis

IBM SPSS (Statistical Package for Social Science) was used to gather, edit, code, and enter data (IBM Corp., IBM SPSS Statistics for Windows, Version 27.0, Armonk, NY: IBM Corp.).The quantitative data was displayed as ranges, means, or standard deviations. Additionally, qualitative characteristics were shown as percentages and numbers. When comparing qualitative data, the Chi-square test and/or Fisher exact test were used when any cell's predicted count was less than 5. Using quantitative data and a parametric distribution, the independent t-test was used to compare two independent groups. In our investigation, we selected the margin of error to be 5% and the confidence interval to be 95%. A *p-value* of less than 0.05 is therefore regarded as significant.

RESULTS

Our study included 219 adult patients who had done cardiac surgery operations that required CPB during our 18 months study period, including emergency cases and reoperations.

Of these 219 included patients, 203 patients achieved adequate anticoagulation (ACT > 400 seconds) after single dose of heparin without the need for extra dose of heparin or FFP and were classified as the NHR group. The remaining 16 patients all of them reached satisfactory ACT

levels either after receiving extra dose of heparin or FFP and were classified as HR group.

Description for studied parameters is shown in (Table 1).

Preoperative characteristics of the patients are summarized in (Table 2).

Compared with the NHR group, the HR group included significantly more men with a 93.8% in HR group compared to 63.1% in the NHR group, smokers showing a high significant difference being 81.2% in HR group compared to 41.6% in non HR group, old age showing a mean age of 60.63 in HR group compared to 54.73 in NHR group and Finally Hypertension showing 87.5% in HR group compared to 56.2% in NHR group.

On the Other Hand body weight and history of diabetes showed statistically non-Significant differences.

Table 1: Descriptive for the studied parameters.

		No. = 219
Age (yrs)	Mean±SD	55.16 ± 9.36
	Range	28 – 78
Smoking	No	118 (55.4%)
	Yes	95 (44.6%)
Sex	No	76 (34.7%)
	Yes	143 (65.3%)
Weight	Mean±SD	79.2 ± 12.66
	Range	48 – 117
DM	No	60 (27.4%)
	Yes	159 (72.6%)
HTN	No	92 (42.0%)
	Yes	127 (58.0%)
ACT post loading	Mean±SD	538.88 ± 96.83
	Range	175 – 725
ACT post loading	ACT post loading < 400	16 (7.3%)
	ACT post loading > 400	203 (92.7%)

Table 2: Comparison between patients with ACT post loading more than and less than 400 regarding age of the studied patients.

		ACT post loading < 400	ACT post loading > 400	Test value	*P-value*	Sig.
		No. = 16	No. = 203			
Age (yrs)	Mean±SD	60.63 ± 10.70	54.73 ± 9.13	2.452•	0.015	S
	Range	37 – 73	28 – 76			
Smoking	No	3 (18.8%)	115 (58.4%)	9.404*	0.002	HS
	Yes	13 (81.2%)	82 (41.6%)			
Sex	Females	1 (6.2%)	75 (36.9%)	6.167*	0.013	S
	Males	15 (93.8%)	128 (63.1%)			
Weight	Mean±SD	78.63 ± 12.25	79.25 ± 12.72	-0.189•	0.851	NS
	Range	57 – 97	48 – 117			
DM	No	6 (37.5%)	54 (26.6%)	0.886*	0.347	NS
	Yes	10 (62.5%)	149 (73.4%)			
HTN	No	2 (12.5%)	89 (43.8%)	5.999*	0.014	S
	Yes	14 (87.5%)	114 (56.2%)			

P>0.05: Non significant (NS); *P*<0.05: Significant (S); *P* <0.01: Highly significant (HS)
*: Chi-square test; •: Independent t-test

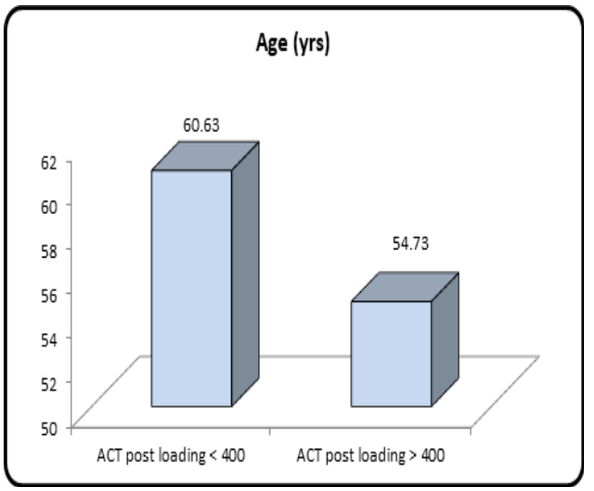

Fig. 1: Comparison between patients with ACT post loading more than and less than 400 regarding age of the studied patients

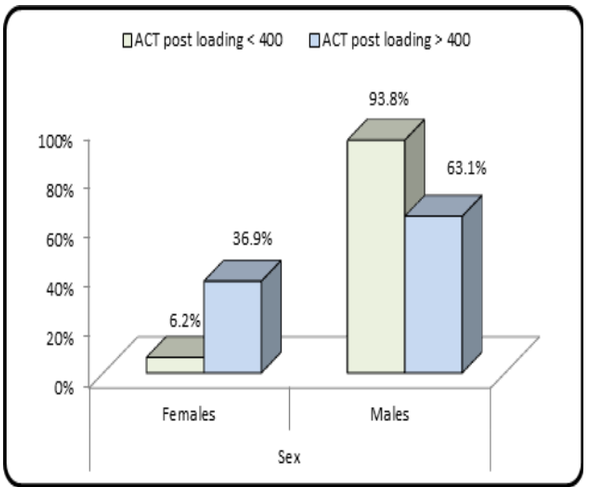

Fig. 2: Comparison between patients with ACT post loading more than and less than 400 regarding sex distribution of the studied patients

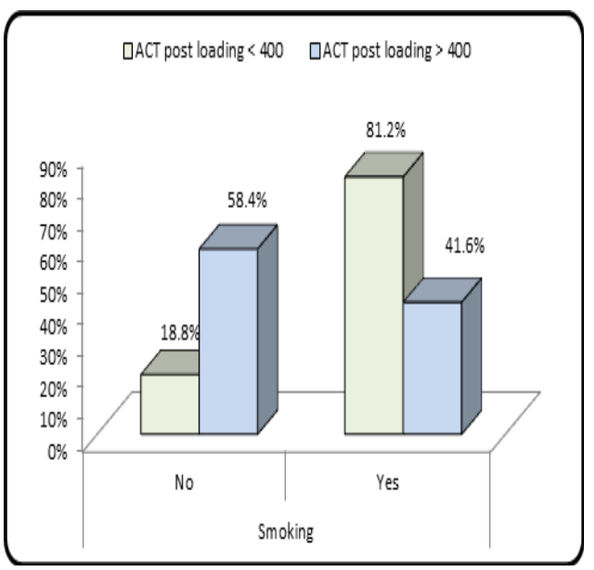

Fig. 3: Comparison between patients with ACT post loading more than and less than 400 regarding percentage of smokers of the studied patients

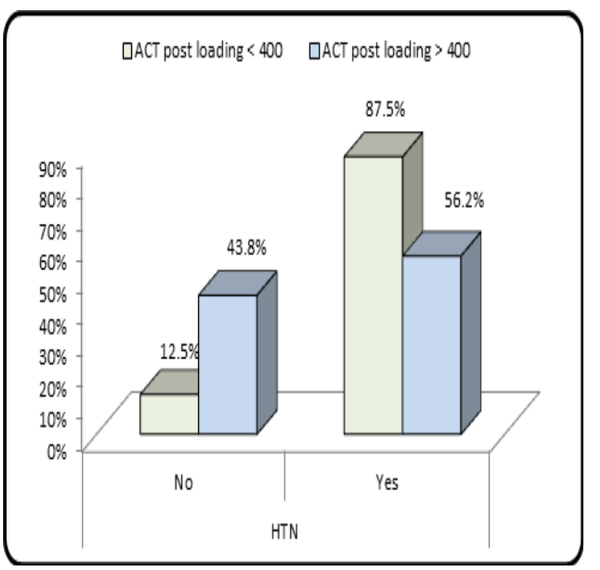

Fig. 4: Comparison between patients with ACT post loading more than and less than 400 regarding percentage of patients with hypertension among the studied patients

DISCUSSION

The incidence of heparin resistance was 16 patients out of 219 showing a percentage of 7.3 % which falls within the range given by (***Alan Finley et al.*** 2019) who conducted a research and mentioned incidence of heparin resistance during cardiac surgery ranging from 4% to 26%[8-12].

Our results also comes very close to (***Naeem et al.*** 2022) who conducted a research on 124 patients undergoing open heart surgery and came out with incidence rate of 8.06 %[13].

Another study conducted by (***Nagler et al.*** 2024) on 197 patients requiring ECMO support and results showed 33 patients (16.8%) required UFH > 35 000 IU/d and 14 patients (7.1%) required UFH > 20 IU/kg/h [14].

In our study we discovered a significant relation between increasing age and HR with a p value of 0.015 showing mean age for patients developing HR to be 60.6 compared to 54.7 in the non HR group (Figure 1) were the same results were conducted by a paper done by (***Grichnik et al.***)[7] who discovered Two unexpected results. First, it was found that ACT prolongation was caused by a moderate heparin resistance that increased with age. According to their prediction, the ACT will drop by 16.5–17.0 seconds for every ten years of age increase. Second, despite the standard justification for heparin dosage, the dose effect of heparin on ACT prolongation was surprisingly weak[15]. Heparin resistance with aging runs counter to the majority of medication effects in the elderly, where individuals are observed to become more sensitive with age[16].

Along with a low antithrombin level, Ranucci and colleagues proposed that older age (>65 years) was a risk factor for HR in patients receiving coronary artery bypass grafting.)[17].

Exact reason behind such findings are still unclear however this was explained possibly by A) people may become more hypercoagulable as they age, and B) changes in the way heparin binds to antithrombin III may occur as people age[18].

A poor heparin dosage response to ACT prolongation could possibly have other explanations. Aspirin, NSAIDS, trental, ticlid, and preoperative heparin and/or nitroglycerin infusions are among the medications frequently prescribed to cardiac surgery patients. It's possible that thrombolytic medications were used before surgery. Ventricular assist devices and intraaortic balloon pumps were used by a few patients.

In our study we found a significant relation between being male and being more liable to having HR with a *P value* of 0.013 and out of the 16 patients with HR 15 were males (93.8%) (Figure 2).

The same results were shown in a paper conducted by (***Liliane C. Roosendaal et al.*** 2022) on non cardiac arterial patients All patients undergoing elective NCAP using heparin and ACT measurements between January 2016 and March 2020 were a total of 778 patients were included and it came what with a conclusion that Heparin infusion during NCAPs caused higher ACTs in females than in males[19].

Same results were conducted by a paper published by (***Vikram Raghunathan et al.*** 2021) that was conducted on ECMO patients and studied 67 patients and concluded that it was more likely for males to develop heparin resistance (82.4% vs. 48.5%, $p = 0.005$) compared with those without heparin resistance[20].

Satoshi and his colleagues as well found a significant correlation between males and HR with 21 out of the 25 patients (84%) with HR being males with a *P value* of 0.011.

It is still unclear why it is more likely for males to develop HR compared to females, but some theories relate that to different levels of inflammatory markers or coagulation factors between males and females. This is borne out by clinical data that shows significantly higher rates of venous thrombosis in males[21].

A highly significant correlation between smoking and HR was discovered in our study were 13 patients(81.2%) out of the 16 patients that showed HR were smokers giving a *P value* of 0.002 (Figure 3), nearly the same results were discovered by a paper conducted on 489 patients undergoing cardiovascular operations (***Satoshi Kawatsu et al.*** 2018). Of these, 25 patients presented with HR paper showed a strong correlation between smoking and HR were 15 patients out of the 25 with HR were smokers giving a *P value* of 0.001[22].

Some theories relates HR to smoking by explaining that nicotine in cigarettes activate the function of the platelet and so subsequently activates the inflammation process, thereby increasing coagulability[23,24].

Smoking also increases inflammatory markers, for example high-sensitivity CRP, interleukin-6, and fibrinogen[25].

Other theories highlights the role of carbon monoxide inhaled in cigarette smoking as Carbon monoxide is a superoxide radical and so it starts an oxidative stress. Carbon monoxide also affects inflammatory cells and plays a role in platelet activation and aggregation cascades[26,27].

From what was discussed earlier we can clearly say that smoking plays a direct role on HR. Interestingly, COPD was a predictor of HR in the study of Satoshi and colleagues were with a *P value* of 0.01.

It is unclear whether COPD has a direct effect on HR or not, Some theories suggest the mechanism could be partially due to the close proximity between COPD and smoking, knowing that smoking is one of the most common causes of COPD[28].

Also COPD is known to be a chronic inflammatory disease, that would subsequently cause a rise in inflammatory biomarkers, such as CRP and fibrinogen[29,30].

Based on the previous speculations, COPD is now considered to be one of the risk factors of HR.

A significant correlation was also found between hypertension and heparin resistance (Figure 4) upon searching in literature we didn't find much papers discussing correlation between hypertension and HR and no clear explanation could be found in such case yet, this could be related to the very high prevlance of hypertension among elderly Egyptian males.

No significant correlation was found between body weight or having DM and developing HR same results were shared by other authors (***Satoshi Kawatsu et al.*** 2018),

CONCLUSION

From our limited study on adult patients undergoing Cardiac surgery using CPB we could conclude that old age, history of smoking male sex and Hypertension are significant risk factors for developing HR.

LIMITATIONS

We used modest sample size in view of the low incidence of heparin resistance being 7-8 %.

We didn't perform genetic studies for patients with HR as it is not performed in Ain shams university as part of routine workup.

Etiology of HR is still unclear and requires further studies and investigations in order to be able spare the patients the dramatic outcomes of insufficient or over anticoagulation such as thromboembolic phenomena, excessive postoperative bleeding, and consumptive coagulopathy.

AUTHOR CONTRIBUTION

Preoperative assessment and decision making was done by Authors 2,3,4 and 5.

Operation was performed by Authors 1,2,3,4.

Data collection was done by author 1,3 and author 5.

Statistical analysis was done by Author 1,2 and 5.

Manuscript writing was done by author 1, 2, and 5.

Proof editing was done by author 2,4 and 5.

CONFLICT OF INTEREST

There is no conflicts of interest.

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المؤشرات الديموغرافية لمقاومة الهيبارين لدى المرضى الذين يخضعون لعمليات القلب المفتوح بأستخدام ماكينه القلب الصناعى

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المقدمة: سمح الهيبارين باستخدام مضادات التخثر الآمنة لأستخدام ماكينة القلب الصناعى فى عمليات القلب المفتوح، ومن هنا تأتي أهمية الفهم الكامل والتنبؤ بحدوث مقاومة الهيبارين.

الهدف: التنبؤ بتأثير العوامل الديموغرافية بين المرضى البالغين الذين يخضعون لجراحة القلب باستخدام ماكينة القلب الصناعى فى عمليات القلب المفتوح على خطر الإصابة بمقاومة الهيبارين.

المنهجية: قمنا في دراستنا بتضمين ٢١٩ مريضًا مختارًا خضعوا لجراحة القلب باستخدام ماكينة القلب الصناعى فى عمليات القلب المفتوح ، وعلى مدى فترة زمنية قدرها ١٨ شهرًا، تم إدراج جميع العوامل الديموغرافية وتحليلها.

النتائج: من بين ٢١٩ مريضًا شملتهم الدراسة، اعتُبر ١٦ مريضًا مقاومًا للهيبارين، وعند تحليل البيانات الديموغرافية لتلك المجموعة، أظهرت الدراسة وجود عدد أكبر بكثير من الرجال والمدخنين وكبار السن ومرضى ارتفاع ضغط الدم.

الخلاصة: يعد زيادة العمر وارتفاع ضغط الدم والتدخين والجنس الذكوري عوامل خطر مهمة للإصابةبمقاومه الهيبارين بين المرضى البالغين الذين يخضعون لجراحة القلب باستخدام ماكينة القلب الصناعى فى عمليات القلب المفتوح.