Archivos de Cardiología de México

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ORIGINAL RESEARCH ARTICLE

# Safety of helicopter transport in patients with acute coronary syndrome

## *Seguridad del transporte en helicóptero en pacientes con síndrome coronario agudo*

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## Abstract

**Background:** *ST-elevation myocardial infarction (STEMI) systems of care have reduced inter-hospital transfer times and facilitated timely reperfusion goals. Helicopters may be an option when land transportation is not feasible; however, the safety of air transport in patients with acute coronary syndrome (ACS) is a factor to consider.* **Objetives:** *The aim of this study was to evaluate the safety of helicopter transport for patients with ACS.* **Methods:** *Prospective, observational, and descriptive study including patients diagnosed with ACS within the STEMI network of a metropolitan city transferred by helicopter to a large cardiovascular center to undergo percutaneous coronary intervention. The primary outcome of the study was the incidence of air-travel-related complications defined as IV dislodgement, hypoxia, arrhythmia, angina, anxiety, bleeding, and hypothermia. Secondary outcomes included the individual components of the primary outcome.* **Results:** *A total of 106 patients were included in the study; the mean age was 54 years and 84.9% were male. The most frequent diagnosis was STEMI after successful fibrinolysis (51.8%), followed by STEMI with failed fibrinolysis (23.7%) and non-reperfused STEMI (9.4%). Five patients (4.7%) developed at least one complication: IV dislodgement (1.8%) and hypoxemia (1.8%) in two patients and an episode of angina during flight (0.9%). A flight altitude of > 10,000 ft was not associated with complications.* **Conclusions:** *The results of this study suggest that helicopter transportation is safe in patients undergoing acute coronary syndrome, despite the altitude of a metropolitan area.*

***Keywords:*** *Acute coronary syndrome. Air travel. Aircraft. Mexico.*

## Resumen

**Antecedentes:** *Los sistemas de atención de IAMCEST han reducido los tiempos de transferencia interhospitalaria y han facilitado las metas de reperfusión oportuna. Los helicópteros pueden ser una opción cuando el transporte terrestre no es factible; sin embargo, la seguridad del transporte aéreo en pacientes con síndrome coronario agudo (SICA) es un factor a considerar.* **Objetivos:** *Evaluar la seguridad del transporte en helicóptero para pacientes con SICA.*

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Date of reception: 14-02-2023
Date of acceptance: 07-07-2023
DOI: 10.24875/ACM.23000044

Available online: 1-3-2024
Arch Cardiol Mex. 2024;94(1):65-70
www.archivoscardiologia.com

**Métodos:** *Estudio prospectivo, observacional, descriptivo. Se incluyeron pacientes con diagnóstico de SICA dentro de la red IAMCEST en metrópolis extensa, trasladados en helicóptero a un centro cardiovascular. El resultado primario del estudio fue la incidencia de complicaciones relacionadas con los viajes aéreos definidas cómo desalojo de catéter intravenoso, hipoxia, arritmia, angina, ansiedad, sangrado e hipotermia.* **Resultados:** *Total de 106 pacientes; la edad media fue de 54 años y 84,9% eran hombres. La altitud media de vuelo fue de 10,100 pies y la distancia media de vuelo fue de 50,0 km. El diagnóstico más frecuente fue IAMCEST tras fibrinolisis exitosa (51,8%), seguido de IAMCEST con fibrinolisis fallida (23,7%). Cinco pacientes (4,7%) desarrollaron una complicación: desalojo IV (1,8%) e hipoxemia (1,8%) en dos pacientes y un episodio de angina durante el vuelo (0,9%). Una altitud de vuelo mayor de 10,000 pies no se asoció a complicaciones.* **Conclusiones:** *Los resultados de este estudio sugieren que el transporte en helicóptero es seguro en pacientes con SICA, incluso en altitudes > 10,000 pies.*

***Palabras clave:*** *Síndrome coronario agudo. Transporte aéreo. Aeronave. México.*

## Introduction

Total ischemic time is a strong predictor of outcomes in patients with ST-elevation myocardial infarction (STEMI)[1]. STEMI systems of care are designed to reduce transfer times to reach optimal reperfusion treatment. However, multiple obstacles could delay patient transfer within STEMI networks.

Helicopter transportation may be a feasible method to reduce transfer times. However, safety is an aspect that should be accounted for, considering the physiological changes that occur during flights above 8,000 feet in non-pressurized cabins[2]. In healthy people, these physiological changes are commonly asymptomatic and benign, but in those with cardiovascular disease, $SatO_2$ can decrease and hypoxia is known to be a stimulus that triggers arrhythmias and angina[3]. Hypothermia may also complicate the course of disease in patients with ACS. Moreover, helicopter transportation requires skilled personnel, and technical complications such as IV dislodgement, fortuitous extubation, and others may happen[3]. This scenario may be of relevance when takeoff and landing altitudes are > 8,000 ft[4].

The aim of this study was to evaluate the safety of helicopter transport for patients with ACS.

## Materials and methods

### *Study design and participants*

We conducted a prospective, observational, and descriptive study including consecutive patients with ACS transferred through helicopter to the emergency room and coronary care unit of the Ignacio Chavez Institute of Cardiology between September 30, 2021, and May 17, 2022. Transportation was provided by the air rescue unit of the State of Mexico “Relámpago,” as well as the Mexico City Police Department Emergency Medical Services helicopters “Condors.” Exclusion criteria consisted of patients without complete demographic data (age or gender) or flight data (height and registry of complications).

Acute coronary syndrome (ACS) was classified according to international nomenclature and clinical practice guidelines as STEMI defined as ST-segment elevation higher than 1 mm in two anatomical consecutive EKG leads[5], non-STEMI (NSTEMI) and unstable angina according to high sensitivity cardiac troponin levels[6]. Failed fibrinolysis was defined as electrocardiographic markers of failed reperfusion (failure to reduce 50% of maximal ST elevation) 60-90 min after administration of fibrinolytic or hemodynamic/electrical instability, worsening of ischemia, or persistent chest pain[5].

### *Data acquisition*

Baseline patient characteristics including relevant medical history (e.g., cardiovascular risk factors such as arterial systemic hypertension, obesity, smoking, and previous ischemic heart disease.), as well as important features of clinical presentation (Killip and Kimball, TIMI, and GRACE scores) and specific timelines of myocardial reperfusion (symptom onset, first medical contact, total ischemia time, etc.) were assessed by research fellows during hospital admission. Flight time, altitude, origin and destination, and the presence of complications during flight were evaluated in collaboration with helicopter transfer paramedical and medical personnel from Relámpago and Cóndores.

### *Primary and secondary endpoints*

The primary endpoint of the study was the incidence of air-travel-related complications defined as hypoxia, arrhythmia, angina, anxiety, bleeding hypothermia, and

IV dislodgement. Secondary endpoints were the individual components of the primary outcome.

Hypoxia was defined as persistent $SpO_2$ < 90% despite supplementary oxygen. Arrhythmia was defined as any clinically relevant rhythm disturbance (bradyarrhythmia or tachyarrhythmia with either supraventricular or ventricular origin) allegedly attributed to air transportation. Angina was defined as persistent or increasing chest pain with angina characteristics. Anxiety was defined as a feeling of worry, or unease accompanied by signs and symptoms such as tachycardia, headache, sweating, and trembling. Bleeding was defined according to the Bleeding Academy Research Consortium criteria. Hypothermia was defined as a body temperature below < 35°C. IV dislodgement was defined as unintentional displacement of intravenous catheter.

## *Statistical analysis*

A descriptive analysis of the quantitative variables was executed. According to their normality, corroborated by the Shapiro-Wilk test, variables were described using mean and standard deviation, if parametric, or median and interquartile ranges, if non-parametric. Qualitative variables were described by means of frequencies and percentages, while the $\chi^2$ test or Fisher's exact test was used for their bivariate analysis, depending on the number of events collected. The association between patient diagnosis, flight altitude, and flight complications was assessed by means of bivariate analysis significance was established at $p < 0.05$ for all comparisons. All analyses were performed using STATA v13 software (StataCorp LP, College Station, Tx). The present study complies with ethical standards and Declaration of Helsinki.

## Results

A total of 106 patients were included in the study. The mean age of patients was 54 years (± 10 years SD) and patients were predominantly male (84.9%). The prevalence of cardiovascular risk factors was: smoking (56.4%), systemic arterial hypertension (45.2%), type 2 diabetes (30.1%), obesity (26.4%), dyslipidemia (22.6%), and a history of ischemic heart disease (11.3%). A complete list of clinical baseline characteristics is included in table 1.

The most frequent diagnosis was STEMI after successful fibrinolysis (51.8%), followed by STEMI with failed fibrinolysis (27.3%) and non-reperfused STEMI (9.4%). Regarding infarction location, anterior was the most frequent (41.8%) followed by inferior wall MI (36.7%).

Regarding flight characteristics, the mean distance was 50 km, with 10.8 km being the shortest from the Enrique Cabrera General Hospital in Mexico City and the maximum being 116.6 km from the Tejupilco Regional Hospital in the State of Mexico. The mean altitude was 10,100 feet with a minimum of 8,300 feet and a maximum of 12,607 feet (Fig. 1). All patients received supplemental oxygen through a nasal cannula during flight.

Five patients (4.7%) developed at least one air-travel related complication: IV dislodgement (1.8%) and hypoxemia (1.8%) in two patients with an episode of angina during flight (0.9%). No complication was life-threatening since the patients were not intervened with inotropes, vasopressors, or sedation.

One patient who presented hypoxemia was diagnosed with posterior inferior STEMI with successful thrombolysis, Killip Kimball Class 1, and flight height at 8300 feet. The second patient with hypoxemia occurred in a failed fibrinolysis anterior STEMI, Killip Kimball Class 3, and flight height at 8237 feet. The patient with angina during the flight was a successful thrombolysis posterior inferior STEMI, Killip Kimball Class 1, and a flight height at 11,211 feet. No statistically significant association between diagnosis and complications ($p = 0.99$) or flight altitude (greater or less than 10,000ft) ($p = 0.14$) and complications were found (Table 2).

## Discussion

The present study suggests that helicopter transfer of patients undergoing ACSs is safe, even during high-altitude flights.

The implementation of STEMI networks has decreased mortality and shortened reperfusion times[7]. However, multiple barriers may delay patient transfer, especially within large networks. These barriers include the lack of universal reperfusion programs, shortage of catheterization laboratories in large geographical extensions, deficiency in diagnostic and reference capacity, and fragmented coordination between the pre-hospital and hospital settings[8]. Helicopter transportation could shorten transfer times and provide a prompt alternative for emergent cases. However, physiological changes that occur during air travel could trigger complications in patients with ACS[2].

When comparing our study population with a series of 6099 patients with ACS traveling by helicopter in Poland, we found that our patients were younger

**Table 1.** Basic demographic characteristics

| Variables | n = 106 |
|---|---|
| Male, n (%) | 90 (84.9) |
| Age, years (± SD) | 54 (± 10) |
| Diabetes, n (%) | 32 (30.1) |
| Arterial hypertension, n (%) | 48 (45.2) |
| Dyslipidemia, n (%) | 24 (22.6) |
| Smoking, n (%) | 60 (56.4) |
| Obesity, n (%) | 28 (26.4) |
| Previous ischemic heart disease, n (%) | 12 (11.3) |
| Previous revascularization (percutaneous or surgery), n (%) | 8 (7.5) |
| Heart rate, bpm median (± SD) | 78 (± 63-92) |
| Systolic blood pressure, mmHg (IQR) | 123 (± 111-134) |
| Diastolic blood pressure, mmHg (IQR) | 75 (± 70-80) |
| Respiratory rate, rpm (IQR) | 18 (± 16-20) |
| Killip Kimball score, n (%) | I: 67 (63)<br>II: 30 (28.3)<br>III: 3 (2.8)<br>IV: 6 (5.6) |
| TIMI score (IQR) | 3 (± 2-5) |
| GRACE score median (IQR) | 113 (± 97-136) |
| Hemoglobin, mg/dL (IQR) | 15.7 (± 14.5-16.9) |
| Creatinine, mg/dL median (IQR) | 0.9 (± 0.8-1.1) |
| Glucose, mg/dL median (IQR) | 132 (± 113-184) |
| NT-proBNP, pg/mL median (IQR) | 993 (± 390-2502) |
| Time to first contact in minutes (IQR) | 150 (± 75-240) |
| Needle door time in minutes (IQR) | 40 (± 17-95) |
| Balloon door time in minutes (IQR) | 65 (± 60-74) |
| Total ischemia time in minutes (IQR) | 274 (± 185-430) |
| Diagnosis, n (%) | Failed thrombolysis 29 (27.3)<br>Successful thrombolysis 55 (51.8)<br>Primary PCI 4 (3.7)<br>No reperfusion 10 (9.4)<br>STEMI 6 (5.6)<br>MINOCA 2 (1.8) |
| Infarct, n (%) | Inferior 36 (36.7)<br>Anterior 41 (41.8)<br>Posterior 12 (12.2)<br>Posterior inferior 2 (2)<br>Extensive anterior 7 (7.1) |
| Distance from first contact to INC kilometers median (IQR) | 50 (± 27-58.7) |

*(Continues)*

**Table 1.** Basic demographic characteristics *(continued)*

| Variables | n = 106 |
|---|---|
| Time onset of symptoms to transfer hours median (IQR) | 16 (± 7-23) |
| Complications, n (%) | IV dislodgement 2 (1.8)<br>Hypoxia 2 (1.8)<br>Arrhythmia 0 (0)<br>Angina 1 (0.9)<br>Anxiety 0 (0)<br>Bleeding 0 (0)<br>Hypothermia 0 (0) |
| Altitude of flight feet (IQR) | 10,100 (± 8,300-11,300) |

IQR: interquartile range; PCI: percutaneous coronary intervention; STEMI: ST-elevation myocardial infarction; SD: standard deviation.

**Table 2.** Comparison between basic diagnoses and major complications

| Variables | Failed fibrinolysis | Successful fibrinolysis | PCI | STEMI MINOCA | Primary |
|---|---|---|---|---|---|
| Hypoxia | 1 (0.9%) | 1 (0.9%) | 0 | 0 | 0 |
| Angina | 0 | 1 (0.9%) | 0 | 0 | 0 |

PCI: percutaneous coronary intervention; STEMI: ST-elevation myocardial infarction.

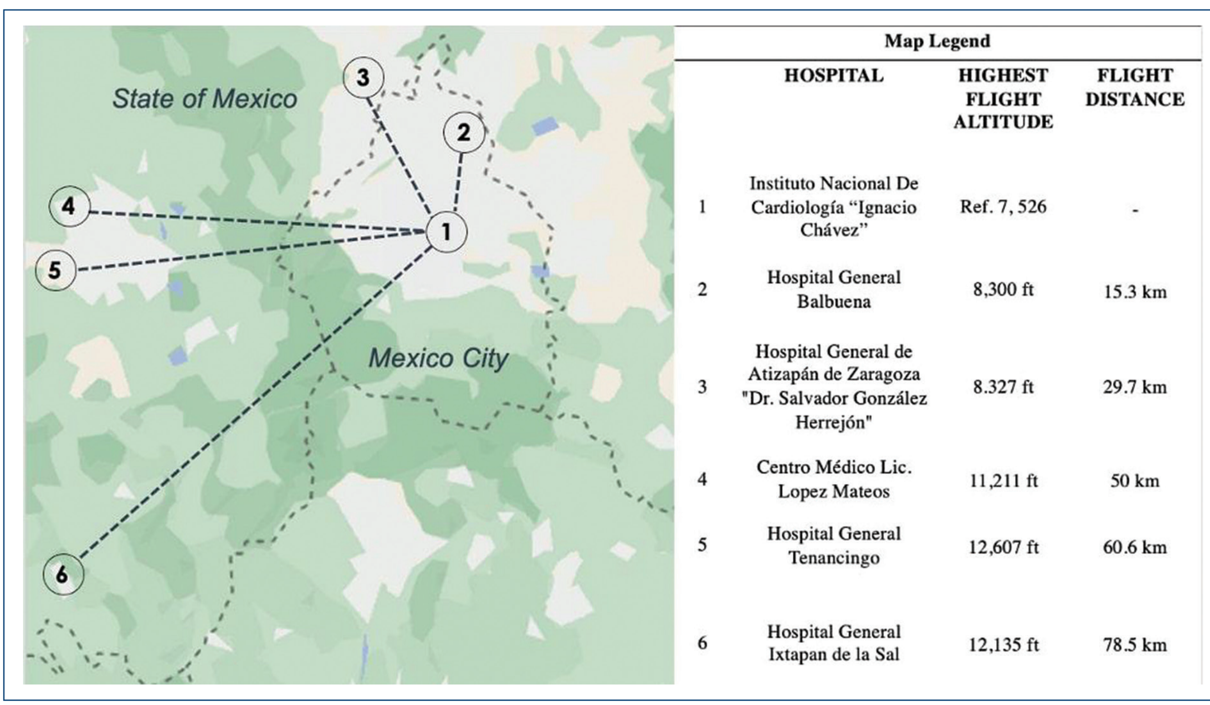


**Figure 1.** Map representing the geographical location of the top 5 referring hospitals.

(54 vs. 64 years) and had a similar average travel distance in both series (50 km)[9]. The authors documented serious arrhythmias during transfer, 4.2% of ventricular tachycardia, and 2.1% in cardiac arrest rhythms. In our series, these rhythm disorders were not reported, even though the sample size was smaller.

Another study in Romania included 45 helicopter transfers in patients with ACS; however, their distances to percutaneous coronary intervention (PCI) center were up to 240 km[10], while in our series the longest was 116.6 km.

Hakim et al. published a study in France comparing the transfer of patients with STEMI to primary PCI in rural areas, of which 410 were by helicopter and 1,501 by land. They found that the primary endpoint of patients arriving to the catheterization laboratory within 90 min was achieved 5 times less in airway transfer patients (9.8% vs. 37.2%; OR: 5.49; 95% CI: 3.90; 7.73; $p < 0.0001$) when the distance traveled was < 50 km. They suggest considering helicopter transfer for distances greater than 50 km, as well as to bear in mind the average cost of 10,000 euros/h of flight[11].

Beyond the analysis of safety, a cost-benefit analysis could further contribute to establishing care protocols for the use of helicopters in patients with ACS. Accounting the aforementioned studies and our own data, the evidence on the safety of helicopter travel of patients with ACS is increasingly solid. This motivates further studies to evaluate the efficacy and cost-effectiveness of helicopter transportation.

Our study shows limitations: a small sample size (although larger than other international registries) and the lack of a comparison group (i.e.: transfer by ambulance). However, our study adds to the literature for the use of helicopter transfer in our region.

## Conclusion

The results of this study suggest that helicopter transportation is safe in patients undergoing ACS, despite the altitude of the metropolitan area of Mexico City. These results may contribute to the strengthening of STEMI systems of care in our region and to facilitate future research and healthcare planning in regard to optimal transfer modalities for patients with ACS.

## Funding

None.

## Conflicts of interest

Alexandra Arias-Mendoza reports speaker-fees for Novartis, Novo Nordisk, Bayer, Pfizer, Sanofi Aventis. Rodrigo Gopar-Nieto reports speaker-fees for Novartis. Jorge Daniel Sierra-Lara Martínez reports speaker and advisory board fees for Novo Nordisk and Novartis. José Luis SBriseño-De la Cruz reports speaker-fees for Sanofi, Boehringer Ingelheim, Menarini, Boston Scientific, Diego Araiza- Garaygordobil reports speaker-fees for Abbott, Asofarma, Astra-Zeneca, Boehringer Ingelheim, Merck, Novartis, Siegfried-Rhein and Servier; Advisory board activities for Silanes and Servier and Research grants for Novartis. All other authors declare no conflict of interest.

## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that no experiments were performed on humans or animals for this study.

**Confidentiality of data.** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Right to privacy and informed consent.** The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

**Use of artificial intelligence for generating text.** The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

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