# Gaps between supply and demand of acute myocardial infarction treatment in Mexico

Ricardo Pérez-Cuevas, DSc,(1) Saúl Eduardo Contreras-Sánchez, MD,(2) Svetlana V Doubova, DSc,(2) Sebastián García-Saisó, MSc,(3) Odet Sarabia-González, MSc,(4) Paulina Pacheco-Estrello, MSc,(5) Alexandra Arias-Mendoza, MD.(6)

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## Abstract

**Objective.** To analyze acute myocardial infarction (AMI) admissions and in-hospital mortality rates and evaluate the competence of the Ministry of Health (MOH) hospitals to provide AMI treatment. **Materials and methods.** We used a mixed-methods approach: 1) Joinpoint analysis of hospitalizations and in-hospital mortality trends between 2005 and 2017; 2) a nation-wide cross-sectional MOH hospital survey. **Results.** AMI hospitalizations are increasing among men and patients aged >60 years; women have higher mortality rates. The survey included 527 hospitals (2nd level =471; 3rd level =56). We identified insufficient competence to diagnose AMI (2nd level 37%, 3rd level 51%), perform pharmacological perfusion (2nd level 8.7%, 3rd level 26.8%), and mechanical reperfusion (2nd level 2.8%, 3rd level 17.9%). **Conclusions.** There are wide disparities in demand, supply, and health outcomes of AMI in Mexico. It is advisable to build up the competence with gender and age perspectives in order to diagnose and manage AMI and reduce AMI mortality effectively.

Keywords: acute myocardial infarction; hospitalizations; in-hospital mortality; supply capacity; reperfusion

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## Resumen

**Objetivo.** Analizar las tendencias de admisiones y mortalidad hospitalaria por infarto agudo al miocardio (IAM) y evaluar la competencia hospitalaria de la Secretaría de Salud (SS) para tratarlo. **Material y métodos.** Enfoque de métodos mixtos: Jointpoint análisis de tendencias de hospitalizaciones y mortalidad hospitalaria entre 2005 y 2017, y encuesta en hospitales de la SS. **Resultados.** Las hospitalizaciones por IAM están aumentando entre hombres y pacientes >60 años. Las mujeres tienen mayor mortalidad. La encuesta incluyó 527 hospitales (2° nivel =471, 3er nivel =56). Los hospitales tienen competencias insuficientes para diagnosticar IAM (2° nivel 37%, 3er nivel 51%), realizar perfusión farmacológica (2° nivel 8.7%, 3er nivel 26.8%) y reperfusión mecánica (2° nivel 2.8%, 3er nivel 17.9%). **Conclusiones.** Existen disparidades en demanda, oferta y resultados en salud del IAM. Es aconsejable fortalecer las competencias, con perspectivas de género y edad, para diagnosticar y tratar IAM, y reducir su mortalidad efectivamente.

Palabras clave: infarto agudo de miocardio; hospitalizaciones; mortalidad hospitalaria; reperfusión

(1) Division of Social Protection and Health, Interamerican Development Bank. Kingston, Jamaica.
(2) Unidad de Investigación Epidemiológica y Servicios de Salud del Centro Médico Nacional Siglo XXI, Instituto Mexicano del Seguro Social. Mexico City, Mexico.
(3) Centro de Investigación en Políticas, Población y Salud, Universidad Nacional Autónoma de México. Mexico City, Mexico.
(4) Sociedad Mexicana de Calidad en Salud. Mexico City, Mexico.
(5) Alianza Médica para la Salud, AC. Mexico City, Mexico.
(6) Instituto Nacional de Cardiología Ignacio Chávez. Mexico City, Mexico.

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Corresponding author: Ricardo Pérez-Cuevas, DSc. Division of Social Protection and Health, Inter-American Development Bank. Jamaica Country Office. 6 Montrose Rd, Kingston 6, Jamaica.
email: rperez@iadb.org

Ischemic heart disease (IHD) is an acute condition that involves a high risk of death and entails negative social and economic impacts. In 2016, IHD caused 17.3% of worldwide mortality, 18.2% in high sociodemographic index (SDI) countries, and 14.3% in low-and-middle-SDI countries.[1] Acute myocardial infarction (AMI) is the most devastating IHD.[2]

Mexico has higher AMI mortality than European and other Latin American countries. In 2015, the thirty-day AMI mortality after hospital admission among member countries of the Organization for Economic Cooperation and Development ranged between 3.7% in Norway and 28.1% in Mexico.[3] Moreover, in-hospital mortality in Mexico (26.6%) is higher than in Nicaragua (25%), Peru (12%), Argentina (8.8%), Brazil (8.8%), and Colombia (6%).[4-8]

Health outcomes of AMI treatment depend on factors related to both the patient and the health services. On the patient's side, women, older adults, low socioeconomic status individuals, and those uninformed regarding suspicion of AMI symptoms have more probabilities of delaying health-seeking care, or of not receiving specialized care, and, therefore, dying.[9-11] While on the health services side, there are pre-hospital and in-hospital factors that influence health outcomes. Pre-hospital factors include shortage of ambulances equipped with electrocardiography and capability to transmit electrocardiograms (EKG) to the on-call cardiologist.[12-14] In-hospital factors include scarcity of medical doctors trained to diagnose and treat AMI, absence of reperfusion therapy, inadequate adherence to reperfusion therapy guidelines, shortage of thrombolytic drugs, reduced availability of 24-hour hemodynamic rooms, and limited skills of cardiologists to perform percutaneous coronary interventions (PCI).[15,16] Favorable health outcomes of AMI can be achieved when the supply side (i.e. cardiologists, equipment, medicines) meets the patients' needs for access to, and availability and high quality of care.

The pervasive high AMI mortality rates in Mexico justify an in-depth analysis of the supply and demand of AMI health care. On the demand side, estimating the trends of AMI hospitalizations allows ascertaining the changes in its magnitude. On the supply side, an analysis of the competence of the Ministry of Health (MOH) hospitals to treat AMI may inform about existing gaps. Moreover, estimating the in-hospital mortality, which is a short-term health outcome, signals the clinical performance to manage the acute phase of AMI.

Therefore, the objectives of the present study were to analyze the trends of AMI hospitalizations and in-hospital mortality rates between 2005 and 2017 and evaluate the competence of MOH hospitals to diagnose and treat this condition.

# Materials and methods

We used a two-stage mixed methods approach. The first stage analyzed the trends of AMI admissions and in-hospital mortality rates between 2005 and 2017 of all MOH hospitals. The second stage consisted in a nationwide cross-sectional online survey to ascertain the competence of MOH hospitals for providing AMI care.

*Stage 1*: Analysis of trends in hospitalizations and in-hospital mortality. We analyzed the data of hospital discharges and deaths registered in the MOH Health Information System from January 1st, 2005 to December 31st, 2017. The analysis considered the nearest year when the states did not have information for 2005. We selected the registries with diagnoses of AMI according to the following codes of the 10th revision of the International Classification of Diseases (ICD-10): I210-I214, I219, I220, I221, I228, I229, I230- I235.

The AMI hospitalization rate formula was the number of AMI hospitalizations in MOH facilities for each age-sex group, divided by the total number of people (stratified by age and sex) covered by the MOH, and multiplied by 100 000.

The estimation of the AMI hospitalization rates at national and state levels included patients aged 30-60 years and >60 years. We stratified these age groups because the extinct public healthcare insurance program *Seguro Popular* only provided funds for the treatment of AMI patients aged <60 years until 2017. Patients aged >60 years did not receive this benefit; MOH hospitals treated them with their regular resources. The annual reports of the former *Seguro Popular* and the national census were the sources for estimating the amount of people that the MOH covered. The AMI in-hospital mortality rate formula was the number of AMI patients that died during their hospital stay for each age-sex group, divided by the total number of hospitalized AMI patients of each age-sex group and multiplied by 100.

*Stage 2*: From May to August 2016 we conducted an online cross-sectional survey to ascertain the hospitals' competence for providing AMI diagnosis and treatment. The survey sample included all secondary and tertiary level MOH hospitals in the 32 states (n=893); we excluded pediatric hospitals. The General Directorate for Quality of Healthcare and Education (DGCES – acronym in Spanish) of the MOH led the survey. Subsequently, the state quality managers of the DGCES followed up by requesting the local health authorities and hospitals to answer the online questionnaire.

A group of decision-makers (DGCES), cardiologists from the National Institute of Cardiology and researchers from the Mexican Institute of Social Security, and the Inter-American Development Bank (IDB) designed and tested the online questionnaire in two hospitals before distributing it to participating hospitals.

Hospital competence was defined as follows: 1. Hospital competence for diagnosing AMI: availability of personnel trained to diagnose AMI, electrocardiogram equipment (EKG), and enzymes test. 2. Hospital competence to perform pharmacological reperfusion: staff trained, availability of electrocardiograph (EKG), crash cart, antithrombotic treatment, protocol for pharmacological reperfusion and for referring patients to facilities with hemodynamic room. 3. Hospital competence to perform mechanical reperfusion: Personnel trained to perform mechanical reperfusion, availability of EKG, crash cart, antithrombotic treatment, pharmacological reperfusion, and 24/7 hemodynamic room.

In order to identify and measure the hospitals' competence for providing AMI healthcare, the questionnaire covered: 1. Hospital level of care, according to the classification of the MOH, we identified secondary and tertiary care hospitals; infrastructure: laboratory availability of cardiac enzymes tests; equipment such as crash cart, functional defibrillators, electrocardiographs, hemodynamic rooms and medications such as thrombolytic medications, aspirin, heparin, and clopidogrel. 2. Healthcare workforce availability such as a cardiologist and staff trained to perform AMI diagnosis, thrombolytic therapy, and coronary angioplasty.

### Statistical analysis

*Stage 1*: We performed the estimations of the hospitalizations and in-hospital mortality rates and their standard errors using a Microsoft Excel spreadsheet. Then, to analyze the trends in the admission and in-hospital mortality rates we built joinpoint regression models using the software of the Surveillance Research Program of the National Cancer Institute of the United States.[17,18] The joinpoint models serve to identify the moment in which significant changes in a trend occur and estimate the magnitude of the changes in each interval. The years/periods that correspond to each trend were ascertained through the annual percentage changes (APC) and their 95% confidence intervals (95%CI). In order to reduce the possibility that the trends were merely the result of a random fluctuation, we set the necessary data in the linear direction at both ends of each period of analysis. A maximum of two inflection points was sought in each regression, for which we looked for the simplest model that might fit the data, using the weighted least squares technique. The $p$-value of <0.05 was considered statistically significant. The statistical significance of tendencies does not depend on the rates registered at the initial and final years, but to all the years of the period.

*Stage 2*: We performed a descriptive statistics analysis of the capacity of secondary and tertiary care hospitals to provide AMI diagnosis and treatment, using the Stata 14 software.

## Results

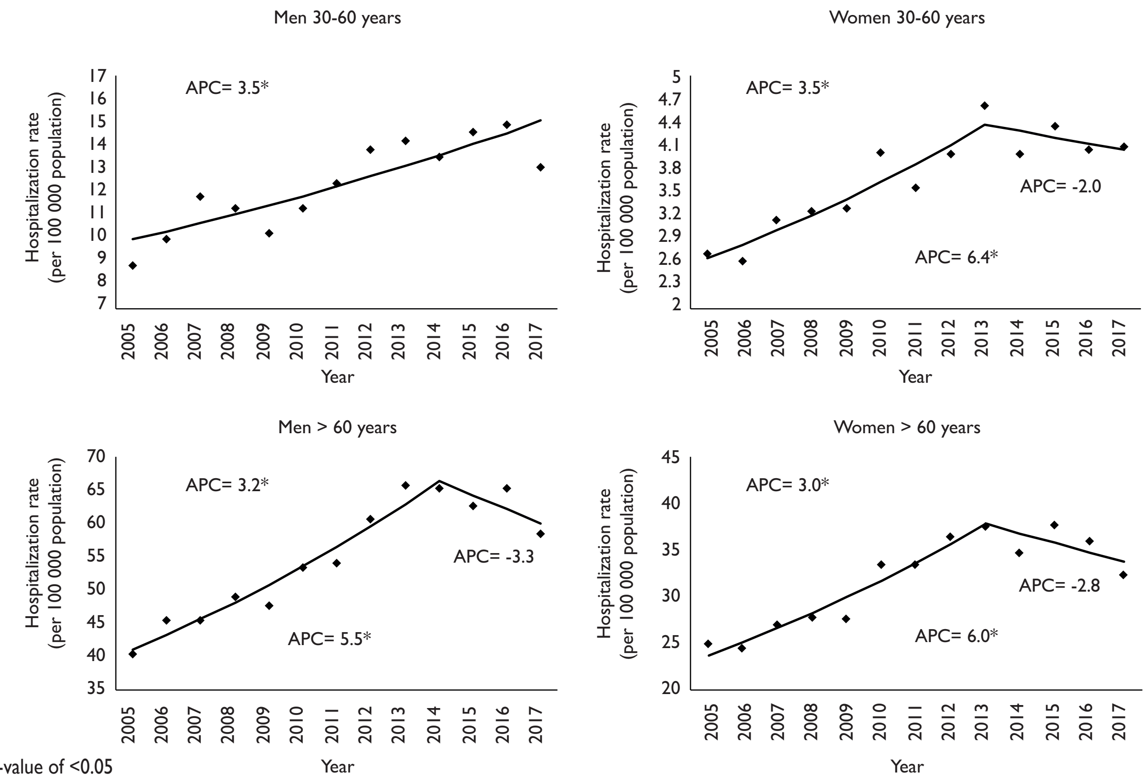
*Stage 1*. Results of the trend analysis for hospitalizations and in-hospital mortality due to AMI during 2005-2017.

AMI hospitalization rates were higher in men compared to women and in patients aged >60 years compared to those 30-60 years old. Figure 1 depicts the trends from 2005 to 2017 of AMI hospitalization rates (per 100 000 population) by sex and age at a national level. In men aged 30-60 years, the AMI hospitalization rate increased from 8.9 to 13.1. In men aged >60 years, it increased from 40.4 to 58.4. The AMI hospitalization rate per 100 000 increased from 2.7 to 4.1 in women aged 30-60 years, and from 25.0 to 32.3 in women aged >60 years.

The AMI in-hospital mortality was higher in women compared to men, and in people older than 60 years compared to those aged 30-60 years. Figure 2 shows national trends in AMI in-hospital mortality rates (per 100 discharges). The AMI in-hospital mortality rate showed a slight upward trend from 2005 to 2017; although it was statistically significant in men aged 30-60 years, during 2005-2017, it increased from 11.5 to 14.6 deaths per 100 discharges (APC 1.8; 95%CI: 0.1, 3.5).

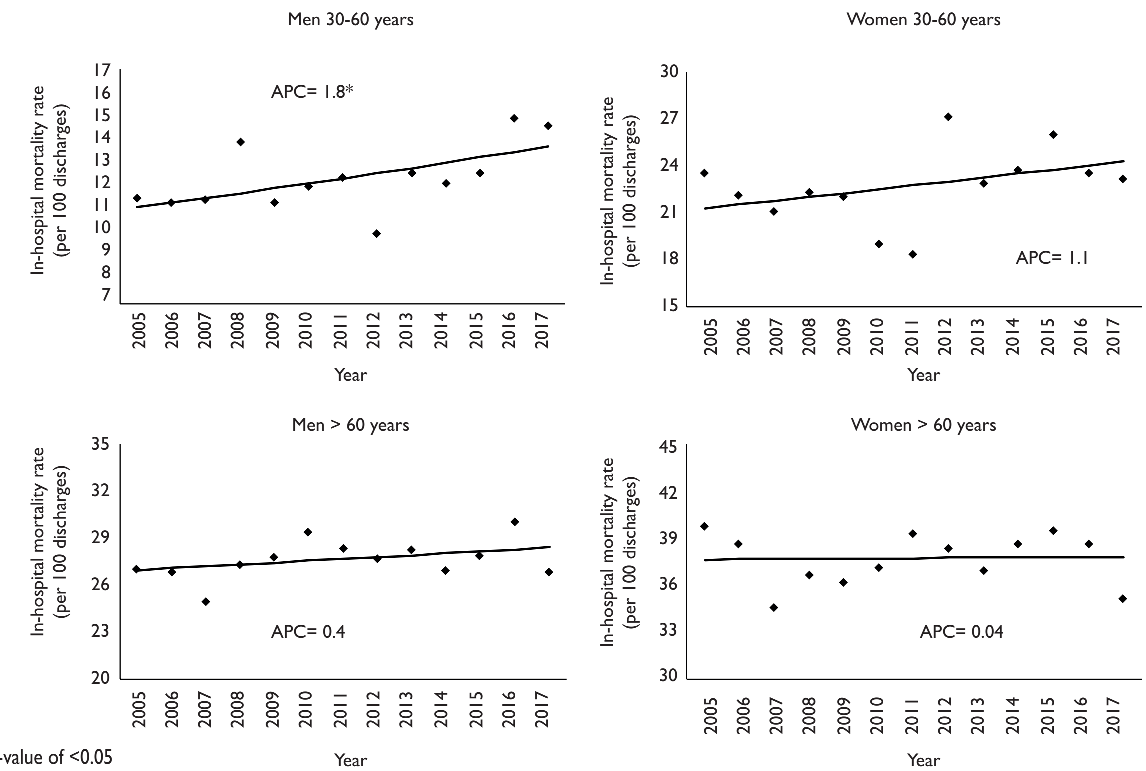
The analysis of hospitalization rates per 100 000 adults showed an upward tendency (table I). The increase in hospitalization rates was statistically significant in 19 states. The highest increases among men aged 30-60 years happened in Aguascalientes, Sinaloa, Sonora, and Zacatecas, and in Guanajuato, Sonora and San Luis Potosi, among men aged >60 years. Among women aged 30-60 years it rose in eight states, mainly in Michoacán, Guanajuato, and Puebla, and among women >60 years old, in Sinaloa, Guanajuato, and Tabasco, and decreased in Colima and Tamaulipas.

Between 2005 and 2017, the in-hospital mortality rate exhibited an upward tendency among men aged 30-60 years in Chihuahua, Jalisco, and Veracruz, and in men aged >60 years, in Chihuahua, Guanajuato and Tamaulipas. It decreased in Aguascalientes, Campeche, and Puebla (table II). Among women aged 30-60 years, it increased in Hidalgo and Veracruz, and in Guanajuato and Morelos among women aged >60 years, and decreased in Aguascalientes and Nayarit. The highest




* p-value of <0.05

**Figure 1. Acute myocardial infarction hospitalization rates between 2005-2017. Mexico**




* p-value of <0.05

**Figure 2. Acute myocardial infarction in-hospital mortality rates between 2005-2017. Mexico**

**Table I**

**Trends in hospitalization rates (per 100 000 population) of acute myocardial infarction at Ministry of Health Hospitals between 2005-2017. Mexico**

| State | Men | | | | Women | | | |
|---|---|---|---|---|---|---|---|---|
| | 30-60 years | | >60 years | | 30-60 years | | >60 years | |
| | 2005 | 2017 | 2005 | 2017 | 2005 | 2017 | 2005 | 2017 |
| Aguascalientes | 25.55 | 33.05* | 169.03 | 130.4 | 6.54 | 11.85 | 58.98 | 83.1 |
| Baja California | 2.35 | 7.56 | 20.91 | 22.29 | 0.8 | 1.12 | 4.67 | 7.87 |
| Baja California Sur | 18.43 | 43.13 | 281.71 | 155.79 | 4.35 | 10.14 | 66.14 | 58.39 |
| Campeche | 9.66 | 9.39 | 42.87 | 69.63* | 3.12 | 3.24 | 46.43 | 37.42 |
| Chiapas | 10.53 | 9.64* | 24.04 | 48.41* | 2.43 | 3.82* | 27.81 | 31.14 |
| Chihuahua | 15.61 | 14.14 | 95.7 | 113.0 | 5.51 | 6.67 | 52.33 | 52.57 |
| Coahuila | 6.46 | 10.71* | 46.02 | 51.36 | 1.75 | 3.35 | 20.8 | 36.37* |
| Colima | 20.17 | 14.27 | 169.32 | 63.53* | 9.58 | 3.99 | 117.45 | 63.18* |
| Durango | 21.3 | 30.0 | 108.6 | 142.0 | 6.99 | 4.71* | 99.27 | 47.56 |
| Guanajuato | 10.93 | 16.46* | 37.92 | 114.95* | 2.32 | 5.25* | 25.97 | 53.08* |
| Guerrero | 6.13 | 14.41 | 18.08 | 72.33* | 1.99 | 2.53 | 24.76 | 26.13* |
| Hidalgo | 12.44 | 13.62 | 41.4 | 34.85 | 4.19 | 3.75 | 20.17 | 21.5 |
| Jalisco | 5.98 | 11.73 | 36.52 | 66.44 | 2.54 | 3.43* | 28.61 | 35.75 |
| Mexico City | 6.56 | 16.88* | 21.54 | 53.8* | 1.82 | 4.31* | 9.47 | 19.99* |
| Michoacán | 6.5 | 10.07 | 38.69 | 32.89* | 2.04 | 5.64* | 13.19 | 36.79* |
| Morelos | 13.37 | 7.05 | 38.16 | 39.34 | 5.28 | 3.52 | 23.33 | 22.63 |
| National | 8.85 | 13.1* | 40.42 | 58.49* | 2.71 | 4.09 | 24.98 | 32.34* |
| Nayarit | 12.54 | 3.55 | 66.94 | 41.88 | 7.2 | 1.67 | 45.01 | 6.02 |
| Nuevo León | 6.26 | 6.58 | 17.72 | 44.62* | 0.25 | 2.81* | 16.72 | 39.5* |
| Oaxaca | 6.0 | 7.44* | 11.92 | 39.4* | 1 | 3.2 | 9.56 | 26.71* |
| Puebla | 3.02 | 12.2* | 15.25 | 38.08* | 1.33 | 5.17* | 6.85 | 24.25* |
| Querétaro | 14.03 | 12.61 | 69.01 | 38.66 | 2.84 | 1.93 | 48.44 | 25.99 |
| Quintana Roo | 4.23 | 13.86* | 9.12 | 80.76 | 2.24 | 3.06 | 9.82 | 16.58 |
| San Luis Potosi | 5.39 | 16.13* | 16.71 | 86.93* | 0.99 | 3.79 | 17.82 | 38.0 |
| Sinaloa | 23.66 | 16.88 | 96.66 | 80.42 | 4.72 | 7.03 | 43.25 | 65.86* |
| Sonora | 13.37 | 24.36* | 59.26 | 93.51* | 6.39 | 6.55 | 68.9 | 45.82 |
| State of Mexico | 1.96 | 6.38 | 11.23 | 29.38* | 0.78 | 2.18* | 5.14 | 15.44* |
| Tabasco | 7.78 | 10.15 | 59.07 | 65.97 | 6.35 | 3.73 | 35.7 | 48.38* |
| Tamaulipas | 27.47 | 24.45 | 88.45 | 91.76 | 6.14 | 4.87 | 86.58 | 59.69* |
| Tlaxcala | 8.63 | 8.23 | 46.15 | 34.32 | 2.21 | 0.78 | 4.67 | 29.13 |
| Veracruz | 13.21 | 17.21 | 54.0 | 44.93* | 4.22 | 4.89 | 30.4 | 28.5 |
| Yucatán | 6.78 | 12.72* | 28.22 | 54.46 | 1.27 | 7.52 | 10.01 | 32.94* |
| Zacatecas | 5.64 | 23.51* | 63.75 | 82.13 | 6.05 | 8.57 | 39.14 | 57.57 |

* $p<0.05$

**Table II**

**TRENDS IN-HOSPITAL MORTALITY (PER 100 DISCHARGES) DUE TO ACUTE MYOCARDIAL INFARCTION AT MINISTRY OF HEALTH HOSPITALS DURING 2005-2017. MEXICO**

| State | Men | | | | Women | | | |
|---|---|---|---|---|---|---|---|---|
| | 30-60 years | | >60 years | | 30-60 years | | >60 years | |
| | 2005 | 2017 | 2005 | 2017 | 2005 | 2017 | 2005 | 2017 |
| Aguascalientes | 15.0 | 18.92 | 25.93 | 12.12* | 33.33 | 6.67 | 45.45 | 12.0* |
| Baja California | 16.67 | 11.11 | 12.5 | 20.0 | 16.67 | 25.0 | 16.67 | 50.0 |
| Baja California Sur | 11.11 | 11.43 | 28.57 | 13.04 | 50.0 | 12.5 | 40.0 | 22.2 |
| Campeche | 33.33 | 37.5 | 83.33 | 14.29* | 100.0 | 33.33* | 33.33 | 87.5 |
| Chiapas | 15.15 | 17.5 | 52.94 | 33.33 | 12.5 | 38.89 | 31.58 | 45.45 |
| Chihuahua | 6.98 | 14.29* | 22.64 | 29.03* | 18.75 | 24.0 | 37.5 | 38.0 |
| Coahuila | 14.29 | 10.0 | 25.0 | 20.0 | 36.36 | 40.0 | 50.0 | 28.57 |
| Colima | 10.0 | 20.0 | 15.79 | 36.36 | 33.33 | 66.67 | 64.29 | 41.67 |
| Durango | 20.0 | 30.61 | 42.42 | 16.95 | 44.44 | 25.0 | 45.16 | 54.55 |
| Guanajuato | 14.29 | 13.92 | 31.43 | 35.66* | 20.0 | 33.3 | 33.3 | 50.0* |
| Guerrero | 14.29 | 15.38 | 25.0 | 28.81 | 20.0 | 25.0 | 38.89 | 32.0 |
| Hidalgo | 12.5 | 20.59 | 20.0 | 33.33 | 11.11 | 36.36* | 36.36 | 41.18 |
| Jalisco | 6.25 | 13.1* | 13.04 | 19.01 | 20.0 | 7.41 | 35.39 | 32.47 |
| Mexico City | 14.81 | 23.13 | 29.73 | 52.24 | 23.53 | 32.56 | 60.87 | 59.7 |
| Michoacán | 20.0 | 7.89 | 37.14 | 13.51 | 42.86 | 16.0 | 53.85 | 20.83 |
| Morelos | 11.11 | 8.33 | 7.69 | 47.37 | 12.5 | 14.29 | 11.11 | 30.77* |
| National | 11.51 | 14.56* | 27.07 | 26.82 | 23.5 | 23.2 | 39.7 | 35.1 |
| Nayarit | 10.0 | 25.0 | 40.0 | 15.38 | 66.67 | 50.0 | 70.0 | 50.0* |
| Nuevo León | 8.33 | 8.82 | 23.08 | 22.64 | 100.0 | 13.33 | 50.0 | 12.96 |
| Oaxaca | 12.5 | 21.74 | 10.0 | 15.38 | 22.22 | 16.67 | 33.33 | 25.0 |
| Puebla | 6.67 | 4.92* | 42.86 | 20.0* | 33.33 | 19.35 | 37.5 | 32.5 |
| Querétaro | 11.11 | 13.04 | 29.41 | 26.67 | 25.0 | 50.0 | 78.57 | 16.67 |
| Quintana Roo | 33.33 | 8.7* | 50.0 | 33.33§ | 50.0 | 20.0 | 50.0 | 62.5§ |
| San Luis Potosi | 20.0 | 5.41 | 33.33 | 16.95 | 25.0 | 20.0 | 20.0 | 27.59 |
| Sinaloa | 9.62 | 8.7 | 18.0 | 18.03 | 27.27 | 14.29 | 30.43 | 30.91 |
| Sonora | 3.45 | 11.59 | 11.54 | 12.31 | 21.43 | 15.0§ | 25.0 | 31.43 |
| State of Mexico | 8.7 | 11.76 | 31.82 | 31.07 | 10.0 | 20.51 | 16.67 | 48.44 |
| Tabasco | 38.46 | 9.09 | 25.00 | 12.12 | 18.18 | 16.0§ | 83.33 | 11.54 |
| Tamaulipas | 12.5 | 20.24 | 27.08 | 32.0* | 41.18 | 22.22 | 45.28 | 31.58 |
| Tlaxcala | 10.0 | 11.11 | 22.22 | 44.44 | 100.0 | 100.0 | 100.0 | 22.22 |
| Veracruz | 11.39 | 22.31* | 32.14 | 29.17 | 28.57 | 32.5* | 30.19 | 35.21 |
| Yucatán | 30.0 | 8.0 | 36.36 | 40.63 | 33.33 | 37.5 | 25.0 | 55.0 |
| Zacatecas | 9.09 | 12.9 | 19.05 | 25.0 | 28.57 | 23.08 | 23.08 | 24.0 |

* trends with $p < 0.05$.
§ 2016 was the final year of analysis due to the availability of the information.
The analysis considered the nearest year when the states did not have information for 2005. Aguascalientes: men and women 30-60 years (2006); Baja California: women 30-60 years (2008), women > 60 years (2006); Baja California Sur: men and women > 60 years (2006); Coahuila: women 30-60 years (2006); Colima: women 30-60 years (2012); Oaxaca: women 30-60 years (2007); Puebla: men 30-60 years (2006); Querétaro: women 30-60 years (2006); Quintana Roo: men 30-60 years (2008), men > 60 years (2006), women 30-60 years (2006), women > 60 years (2009); San Luis Potosi: women 30-60 years (2006); Tlaxcala: men 30-60 years (2007), women 30-60 years (2008); Yucatán: men 30-60 years (2006), women 30-60 years (2010); Zacatecas: men 30-60 years (2006).

rates of in-hospital mortality happened in women aged >60 years, in comparison to men of the same age group.

*Stage 2*. The supply capacity of MOH hospitals for the diagnosis and treatment of AMI.

The survey included 527 MOH hospitals (61% of 893 MOH hospitals), of which 471 (89%) were secondary care level hospitals, and 56 (11%) were tertiary care level hospitals. The non-response rate was 39%. We estimated that 26.3 million people over 30 years of age were eligible to receive care in these facilities.

We analyzed the competency of hospitals to diagnose AMI and to perform pharmacological and mechanical reperfusion (table III). Regarding the secondary level hospitals, only 16% were certified by the General Health Council (GHC). Overall, 37% had the competency to diagnose AMI; only 8.7%, to perform pharmacological reperfusion, and 2.8%, to perform mechanical reperfusion. As for tertiary level hospitals, 12% were GHC certified, 51% were competent to diagnose AMI; 26%, to perform pharmacological reperfusion, and 18%, to carry out mechanical reperfusion. There were wide gaps in hospital capacity between states. We detected that nine of the secondary level hospitals (Baja California Sur, Colima, Durango, Hidalgo, Nayarit, Tabasco, Tlaxcala, Yucatán, and Zacatecas) did not have the competence to perform pharmacological reperfusion, while secondary level hospitals in 18 states were not competent to perform mechanical reperfusion. As for tertiary level hospitals, only 12% were CGE certified, and the hospitals of the states of Mexico, Guerrero, Puebla, Sinaloa, Tlaxcala, Veracruz, Yucatán, and Zacatecas had no competence to perform pharmacological or mechanical reperfusion.

Between 2010 and 2015, the hospitals treated 40 071 AMI patients; only 27% received thrombolysis, and 12% underwent angioplasty. The percentage of patients that underwent reperfusion varied by state, ranging from zero reperfusion in Colima, Michoacán, Quintana Roo hospitals, to 54.2% of patients treated with pharmacological reperfusion in Mexico City, and 65.2% treated with mechanical reperfusion in Puebla.

## Discussion

The main results of the study indicate an upward trend of AMI hospitalizations in men aged 30-60 and >60 years, and in women aged >60 years. Besides, in-hospital mortality rates in men and women >60 years of age are on the rise, and MOH hospitals have little competence to diagnose AMI, exhibiting wide disparities, or to perform pharmacological and mechanical reperfusion.

The increasing trend in AMI hospitalizations among patients aged >60 years is similar to what low-and-middle-SDI countries report.[19] The finding is opposite to the downward trends in AMI hospitalizations in high-SDI countries,[20-22] where successful preventive programs encourage the use of outpatient cardioprotective medications.[23] Effective prevention programs to reduce cardiovascular risk factors are an unmet need in Mexico.

In-hospital mortality is a health outcome and a proxy indicator of high quality care. It showed high rates mainly among men and women >60 years, signaling age and gender gaps. The wide disparities of in-hospital mortality rates might be related to the competence of the hospital to manage AMI. Subnational variations are not uncommon; they have been reported in China and Brazil.[24,25] Ascertaining subnational differences can guide targeted interventions to bridge in-hospital mortality gaps. Moreover, a study from Brazil reported that hospital mortality rates increased with age after adjusting for baseline risk differences.[26] Elderly patients have more complex comorbidities and worse outcomes and are less likely to undergo revascularization or receive acute and long-term medications.[27] Access to high-quality care can boost up the reduction of the mortality rate to 50%.[28]

Women had higher rates of AMI in-hospital mortality. Studies from high-SDI countries found a higher risk for in-hospital mortality in women aged >60 years than in their male counterparts.[29,30] This bespeaks a lack of awareness about the risks and a poor recognition of the symptoms of women who have AMI. These are frequently older, suffer atypical symptoms, and present bleeding and vascular complications. Also, delays in medical care and a lower probability of receiving guideline-based pharmacological therapies and revascularization have been reported in women.[31-33]

In 2018, the MOH launched the National Program to Reduce the Mortality due to AMI (PREMIA, Spanish acronym), which developed training materials for medical doctors to diagnose AMI and build clinical guidelines, encouraged the creation of health networks, and promoted pharmacological reperfusion centers, mainly in those states that lacked hemodynamic rooms.[34] However, the PREMIA program lacks impact evaluations or progress reports.

The competence of MOH 2$^{nd}$ and 3rd level hospitals to diagnose AMI and perform pharmacological and mechanical reperfusion is poor, and there are wide gaps among the states. These results signal critical disparities in the strategic planning of healthcare services for patients with AMI. It is possible to assume that the MOH hospital network performance for AMI treatment has been substandard, since the AMI in-hospital mortality increased during the period of the analysis.

Deficiencies on the supply side might explain the disparities in the AMI in-hospital mortality. We found that half of the hospitals had shortages for diagnosing AMI.

**Table III**

**Secondary and tertiary level hospitals competency to manage acute myocardial infarction. Mexico**

| States | Total MOH hospitals in each Statea | Competency of secondary care hospitals | | | | | Competency of tertiary care hospitals | | | | | Thrombolisis % | Mechanical Angioplasty % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | General Health Council Certified n (%) | To diagnose AMI n (%) | To perform pharmacological reperfusion n (%) | To perform mechanical reperfusion n (%) | N | General Health Council Certified n (%) | To diagnose AMI n (%) | To perform pharmacological reperfusion n (%) | To perform mechanical reperfusion n (%) | | |
| National | 893 | 471 | 76 (16.1) | 176 (37.4) | 41 (8.7) | 13 (2.8) | 56 | 7 (12.5) | 29 (51.8) | 15 (26.8) | 10 (17.9) | 27.0 | 12.0 |
| Aguascalientes | 7 | 3 | 1 (33.3) | 2 (66.7) | 1 (33.3) | 0 (0.0) | | | | | | 20.5 | 0 |
| Baja California | 13 | 6 | 3 (50.0) | 4 (66.7) | 3 (50.0) | 1 (16.7) | | | | | | 40.0 | 1.7 |
| Baja California Sur | 7 | 6 | 1 (16.7) | 5 (83.3) | 0 (0.0) | 1 (16.7) | | | | | | 33.6 | 5.6 |
| Campeche | 15 | 10 | 3 (30.0) | 2 (20.0) | 1 (10.0) | 1 (10.0) | 2 | 0 (0.0) | 1 (100.0) | 1 (100.0) | 0 (0.0) | 9.3 | 0.8 |
| Mexico City | 60 | 7 | 2 (28.6) | 7 (100.0) | 6 (85.7) | 0 (0.0) | 5 | 1 (20.0) | 2 (40.0) | 1 (40.0) | 1 (20.0) | 54.2 | 27.5 |
| Chihuahua | 26 | 9 | 3 (33.3) | 7 (77.8) | 4 (44.4) | 0 (0.0) | 2 | 0 (0.0) | 1 (100.0) | 1 (50.0) | 1 (0.0) | 45.0 | 6.0 |
| Coahuila | 22 | 10 | 0 (0.0) | 7 (70.0) | 2 (20.0) | 0 (0.0) | | | | | | 13.0 | 0 |
| Colima | 6 | 3 | 1 (33.3) | 3 (100.0) | 0 (0.0) | 0 (0.0) | | | | | | 0 | 0 |
| Durango | 29 | 25 | 10 (40.0) | 5 (20.0) | 0 (0.0) | 1 (4.0) | 1 | 1 (100.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 16.4 | 11.1 |
| State of Mexico | 88 | 57 | 11 (19.3) | 18 (31.6) | 12 (21.1) | 2 (3.5) | 10 | 10 (100.0) | 6 (60.0) | 3 (30.0) | 3 (30.0) | 42.2 | 2.2 |
| Guanajuato | 43 | 32 | 4 (12.5) | 14 (43.8) | 9 (28.1) | 0 (0.0) | 7 | 0 (0.0) | 7 (100.0) | 2 (28.6) | 1 (14.3) | 22.2 | 0.5 |
| Guerrero | 41 | 29 | 2 (6.9) | 4 (13.8) | 3 (10.3) | 0 (0.0) | 3 | 1 (33.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 34.1 | 0.3 |
| Hidalgo | 19 | 15 | 1 (6.7) | 5 (33.3) | 0 (0.0) | 2 (13.3) | | | | | | 22.5 | 2.2 |
| Jalisco | 46 | 25 | 2 (8.0) | 12 (48.0) | 4 (16.0) | 0 (0.0) | 7 | 0 (0.0) | 2 (28.6) | 1 (14.3) | 0 (0.0) | 5.7 | 0.7 |
| Michoacán | 28 | 18 | 1 (5.6) | 6 (33.3) | 2 (11.1) | 1 (5.6) | 2 | 1 (50.0) | 1 (50.0) | 0 (0.0) | 0 (0.0) | 0 | 0 |
| Morelos | 11 | 9 | 0 (0.0) | 7 (77.8) | 3 (33.3) | 0 (0.0) | 1 | 0 (0.0) | 1 (100.0) | 1 (100.0) | 0 (0.0) | 27.0 | 0 |
| Nayarit | 17 | 11 | 1 (9.1) | 3 (27.3) | 0 (0.0) | 0 (0.0) | | | | | | 16.7 | 0 |
| Nuevo León | 15 | 9 | 3 (33.3) | 8 (88.9) | 2 (22.2) | 0 (0.0) | | | | | | 3.8 | 0 |
| Puebla | 73 | 48 | 5 (10.4) | 11 (22.9) | 6 (12.5) | 1 (2.1) | 3 | 0 (0.0) | 1 (33.3) | 0 (0.0) | 0 (0.0) | 5 | 65.2 |
| Querétaro | 6 | 6 | 3 (50.0) | 5 (83.3) | 2 (33.3) | 0 (0.0) | | | | | | 27.3 | 9.7 |
| Quintana Roo | 11 | 4 | 0 (0.0) | 3 (75.0) | 2 (50.0) | 1 (25.0) | | | | | | 0 | 0 |
| San Luis Potosi | 17 | 12 | 2 (16.7) | 3 (25.0) | 1 (8.3) | 0 (0.0) | 2 | (0.0) | 1 (50.0) | 2 (100.0) | 1 (50.0) | 66.7 | 1.5 |
| Sinaloa | 25 | 20 | 2 (10.0) | 4 (20.0) | 2 (10.0) | 1 (5.0) | 1 | 0 (0.0) | 1 100.0 | 0 (0.0) | 0 (0.0) | 5.7 | 3.7 |
| Sonora | 26 | 17 | 0 (0.0) | 8 (47.1) | 2 (11.8) | 1 (5.9) | | | | | | 15.0 | 0 |
| Tabasco | 28 | 19 | 3 (15.8) | 2 (10.5) | 0 (0.0) | 0 (0.0) | 4 | 0 (0.0) | 3 (75.0) | 0 (0.0) | 2 (50.0) | 16.7 | 9.5 |
| Tamaulipas | 27 | 8 | 2 (25.0) | 5 (62.5) | 4 (50.0) | 0 (0.0) | 1 | 0 (0.0) | 1 (100.0) | 1 (100.0) | 1 (100.0) | 12.3 | 0.7 |
| Tlaxcala | 14 | 10 | 0 (0.0) | 4 (40.0) | 0 (0.0) | 0 (0.0) | 1 | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 40.7 | 0 |
| Veracruz | 64 | 23 | 6 (26.1) | 6 (26.1) | 3 (13.0) | 0 (0.0) | 2 | 1 (50.0) | 1 (50.0) | 0 (0.0) | 1 (50.0) | No data | No data |
| Yucatán | 12 | 7 | 1 (14.3) | 2 (28.6) | 0 (0.0) | 0 (0.0) | 1 | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | No data | No data |
| Zacatecas | 18 | 13 | 3 (23.1) | 4 (30.8) | 0 (0.0) | 1 (7.7) | 1 | 0 (0.0) | 1 (100.0) | 0 (0.0) | 0 (0.0) | 27.1 | 2.5 |

The gray shading means that there was no third-level hospital in the state to provide healthcare for AMI patients. MOH: Ministry of Health AMI: acute myocardial infarction

The EKG recording and interpretation at first medical contact of the patient with AMI symptoms is a primary tool in the early identification and management of AMI,[35] that allows prompt diagnosis, especially in low resource settings. Additionally, few hospitals could perform pharmacological and mechanical reperfusion. Reperfusion therapy in ST-segment elevation AMI (STEMI) is an essential component of the treatment, as it strongly influences short- and long-term patient outcomes.[36] Primary mechanical reperfusion is recommended as the preferred therapeutic reperfusion strategy for all patients with STEMI when it can be performed within 90 mins. After first medical contact, or for patients with contraindications to fibrinolytic drugs, or those in cardiogenic shock; otherwise, pharmacological reperfusion with thrombolytics is crucial. However, we found that only 27% of AMI patients received thrombolysis, and a mere 12% underwent angioplasty. These figures are lower than in other countries. For instance, two prospective studies of acute coronary syndrome survivors from 20 European, Latin American, and eight Asian countries reported that the mechanical reperfusion rate ranged between 24.8% (in India) and 65.6% (in Northern Europe), and fibrinolysis rates, between 8.1% (in China) and 34.2% (in Southeast Asia), which resulted in total reperfusion therapy ranging between 53.9% (India) and 81.2% (Southern Europe).[37]

The study has limitations: first, the analysis used routinely collected data on hospital discharges from the Health Information System of the MOH. The quality of these data regarding the accuracy of the diagnosis of AMI has not been validated in Mexico. Studies from high-SDI countries showed that hospital discharge data are reliable as to the diagnosis of AMI.[38,39] Second, the starting point of our analysis of in-hospital mortality was 2005, or the nearest year with a registry. Third, we estimated in-hospital mortality rates adjusting by age and sex, but we were unable to analyze comorbidity as the cause of death. Fourth, we could not ascertain the competence of the MOH to provide pre-hospital care; therefore, we were unable to identify the barriers to the emergency transportation of patients that were seen in emergency services at outpatient care clinics. Fifth, we were unable to identify patients who were discharged and then re-hospitalized on the same day, which can lead to overestimation of the hospitalization rate.

## Conclusion

Mexican states have wide disparities in demand, supply, and health outcomes of AMI. It is advisable to build up the competence, with gender and age perspectives, to diagnose and perform pharmacological and mechanical reperfusion to reduce AMI mortality effectively.

## Ethics approval and consent to participate

Under the Internal Regulation of the DGCES of the MOH, the Research Ethics Committee of the National Institute of Public Health, the secondary data analysis and voluntary anonymous online survey of hospital managers were considered exempt of approval.

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