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# Mortality from anti-personnel mines before and during the Colombian peace process

## *Mortalidad secundaria a minas antipersona antes y durante el proceso de paz colombiano*

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### What do we know about this problem?

· Mortality as well as the consequences associated with anti-personnel mine injuries are catastrophic.

### What does this study add?

· To our knowledge, this is the first study that shows a positive impact of the negotiation and implementation of a peace process on a type of trauma (landmine injuries) that generally results in poor outcomes.

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### Abstract

**Introduction:** Although the peace process in Colombia resulted in a significant reduction in the number of anti-personnel mines across the country, there are no reliable data on the effects of this phenomenon on outcomes for patients who were victims of these devices.

**Objective:** The objective of this study was to assess mortality from landmine injuries before and during the Colombian peace process. Furthermore possible associations between peace negotiations and mortality were explored.

**Methods:** For this study, we used the "Colombian Victims of Antipersonnel Mines Injuries registry" (MAP/MUSE database) data from 2002 to 2018. This registry was launched in 2001 by the government of Colombia with the aim of prospectively and systematically collect information on all the cases of anti-personnel mine injuries in the country. The period between 2002-2012 was classified as the pre-negotiation period (período de guerra), and 2014-2018 as the peace negotiations period, with 2013 classified as a washout year. Multivariate logistic regression was used to explore the association between peace negotiations and mortality among anti-personnel landmine injured individuals.

**Results:** A total of 10306 landmine injury cases were registered. Of these, 1180 (11.4%) occurred in the peace-negotiation period. Mortality was significantly lower during the period of peace negotiations. After adjusting for sex, age group, race, active duty soldier status, rural area, and geographic Departments case volumes, the peace negotiation period was found to be associated with lower risk-adjusted odds of mortality after suffering a landmine injury (OR= 0.6, 95% CI, 0.5-0.7; p<0.001).

**Conclusions:** Our findings suggest an association between the period of peace negotiation and a lower likelihood of mortality among victims of anti-personnel landmines.

**Keywords:** Wounds and injuries; Amputation; peace; Outcome assessment (health care); Colombia.

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## Resumen

### Introducción

Aunque el proceso de paz colombiano produjo una reducción en la cantidad de minas antipersona en el país, no hay estimativos sobre el efecto de este fenómeno en los desenlaces de los pacientes víctimas de estos artefactos.

### Objetivo

Nuestro objetivo fue evaluar la mortalidad por minas antipersona antes y durante la negociación del proceso de paz en Colombia. Además, exploramos posibles asociaciones entre las negociaciones de paz y la mortalidad.

### Métodos

Para este estudio utilizamos los datos del "Registro de víctimas colombianas de lesiones de minas antipersona" (base de datos MAP / MUSE) de 2002 a 2018. Este registro fue lanzado en 2001 por el gobierno de Colombia con el objetivo de recolectar información de manera prospectiva y sistemática de los casos de trauma por minas antipersona en el país. Clasificamos el período comprendido entre 2002 y 2012 como el período previo a la negociación (período de guerra), el comprendido entre 2014 y 2018 como el período de negociaciones de paz y el año 2013 como período de "depuración". Se utilizaron modelos de regresión logística multivariados para explorar las asociaciones entre las negociaciones de paz y la mortalidad.

### Resultados

Se registraron un total de 10306 casos de lesiones por minas antipersona. De estos, 1180 (11.4%) ocurrieron en el período de negociación de paz. La mortalidad fue significativamente menor durante el período de negociaciones de paz. El análisis de regresión logística multivariado determinó que el período de negociación de paz se asoció con una menor probabilidad de mortalidad después de sufrir una lesión por minas antipersona (OR = 0,6, IC 95%, 0,5-0,7;  $p < 0,001$ ).

### Conclusiones

Nuestros hallazgos sugieren una asociación entre el período de negociación de paz y una menor probabilidad de mortalidad entre las víctimas de las minas antipersona.

### Palabras clave

Heridas y Traumatismos; Amputación; Paz; Evaluación de procesos y resultados de atención en salud; Colombia.

## INTRODUCTION

After more than half a century of suffering the ravages of war, Colombian leaders and politicians decided to embark in a comprehensive process of peace negotiations with the left-wing guerrillas Fuerzas Armadas Revolucionarias de Colombia (FARC-EP), reaching a truce between both parties in November 2012 (1,2). The war in Colombia was one of the oldest low-intensity conflicts active in the twenty-first century (3). During this conflict, millions were internally displaced, injured or killed on the battlefield as a result of the fighting. It has been estimated that the war was the direct cause of 92,946 victims of hostile actions, and 39,000 violence-related deaths since 1988 (4).

One of the deadliest threats that civilians and soldiers had to face during this period was the one posed by anti-

personnel mines, resulting in 11,629 casualties since 1990 and making Colombia one of the countries with the highest rates of anti-personnel landmine casualties in the world. Furthermore, considering that landmine contamination blocked community access to schools, hospitals, and local markets, especially in rural areas, it has been estimated that these devices contributed to the displacement of over six million Colombians since guerrillas started its systematic use in the early 1990s.

Although there are no reliable data estimating the socio-economic effects of antipersonnel landmines in Colombia, it is well known that these devices are a source not only of social but also economic calamities (5,6). Previous studies have shown that the economic consequences of anti-personnel mine-associated injuries are enormous. For example, Edwards et al. (5) analyzed data from 265 casualties

resulting in 416 amputations during the Afghanistan war and estimated the 40-year cost of this cohort at approximately USD 444 million. Moreover, it has been demonstrated that war amputees usually suffer from post-traumatic stress disorder and other psychological symptoms, even many years after their initial injury (7).

These findings should have underpinned the formulation of national strategies aimed at reducing the number and availability of anti-personnel landmines in the country. However, during the Colombian armed conflict, the conditions required for conducting landmine eradication operations were not fulfilled, and it was not until the initiation of the comprehensive peace process (2012) (1,2) that a real opportunity to eliminate these artifacts from Colombian combat arenas arose. During the peace negotiation period (2012-2016), the efforts

made by the leaders of both parties and their commitment to prevent the conflict from resuming, coupled with the commencement of landmine eradication operations, led to a significant reduction in the number of these artifacts across the country, with the subsequent reduction in the number of landmine casualties (8).

The objective of this study was to assess mortality from anti-personnel landmines before and during the Colombian peace process. Potential associations between peace negotiations and mortality were also explored.

## METHODS

This study was reported via the STROBE guidelines for reporting observational, cohort studies.

### Data Source

For this observational study, we used data from the Colombian Victims of Anti-personnel Mine Injuries registry (MAP/MUSE database) which is fully available online and provides publicly de-identified data of all individuals that have been victims of anti-personnel mine injuries in Colombia since 1991 (9). The MAP/MUSE database is a government-sponsored registry that was launched in 2001 with the objective of collecting data of all cases of antipersonnel mine injuries in the country. Although the registry collected retrospective data of landmine victims from 1991 to 2001, systematic collection of prospective data started in 2002.

The dataset used for this study is considered public, i.e., created with the intent of making it available to the public. The data available to the public are not individually identifiable and, therefore, their analysis would not involve human subjects. Thus, it was deemed exempt from ethics committee review at Fundacion Valle del Lili in Cali, Colombia, in accordance with the recommendations contained in

the Universidad del Rosario guidelines for determining whether a study protocol should or not be submitted to ethics committee review. The guidelines were created by the Universidad del Rosario institutional review board and are available online (10).

### Study Population

Records for the time period between 2002 and 2018 were extracted from the Colombian MAP/MUSE database. All individuals registered in the database during this period were included. The database contains information on demographics and outcomes. Specifically, core data elements in the MAP/MUSE include age, gender, ethnicity, place of injury, and outcome (death or alive). It also contains data on civilian or military status of the victims.

### Statistical Analysis

Differences in the characteristics of landmine victims were compared between the pre-negotiation period (war period) and the peace process period using a chi-square test for categorical variables. Mortality was calculated by dividing the number of events (death) by the total number anti-personnel landmine victims during the observation period.

A multivariate regression analysis was used to explore associations between peace negotiations and mortality. For this analysis, the unit of analysis of interest was the individual and not time. Therefore, the focus of interest was individual patient outcomes rather than a sequence of data points recorded at regular time intervals.

Thus, a multivariate regression model, adjusted by sex, age group, race, occupation (soldier vs. civilian), rural area, and geographic areas (departments) based on case-volume was built to study the

association between the peace negotiations period and mortality from landmine injuries. For this analysis, the 2002-2012 period was classified as the pre-negotiation period (war period), 2014-2018 as the peace negotiations period, and 2013 as a washout year. Mortality in the peace negotiations group and the pre-negotiations (war period) group was evaluated on the basis of the estimated odds ratio (OR) with its 95% confidence interval (95% CI), where the pre-negotiation period was set as reference. All analyses were done in Stata 14.

## RESULTS

A total of 10305 individuals were victims of antipersonnel landmine injuries in Colombia during the observation period. Of these, 9124 and 1181 individuals were in the pre-negotiation period (war period) and in the peace negotiations period, respectively.

An overview of landmine victim characteristics stratified by periods is shown in Table 1. There was a significant absolute reduction in the number of victims during the peace negotiations period, compared to the war period. Although there were no differences in the proportion of males, there was a significantly higher proportion of individuals under 18 years of age during the peace negotiations period (under 18y: war period, 825 [9%] vs. peace period, 168 [14.3%];  $p < 0.001$ ).

Overall, 61.3% and 38.7% of individuals were soldiers and civilians, respectively. While there was a decrease in the proportion of soldiers victims of landmines in the negotiation period (war period: 5650 [62%] vs. peace period: 675 [57.1%];  $p = 0.002$ ), there was an increase in the percentage of civilian casualties during the same period (war period: 3474 [38%] vs. peace period: 506 [42.9%];  $p = 0.002$ ). Similarly, there were significant increases in the proportion of indigenous (war period: 311 [3.4%] vs. peace period: 70 [5.9%];

**TABLE 1.** General characteristics and mortality of landmine victims in Colombia, 2002-2018.

	Total (n=10305)	Pre-negotiation period (war period) (n=9124)	Peace Negotiations (n=1181)	p- value
Males, n (%)	9808 (95.1%)	8690 (95.2%)	1118 (94.5%)	0.3
Under 18 years, n (%)	993 (9.6%)	825 (9%)	168 (14.3%)	<0.001
Occupation				0.002
Soldiers, n (%)	6325 (61.3%)	5650 (62%)	675 (57.1%)	
Civilians, n (%)	3980 (38.7%)	3474 (38%)	506 (42.9%)	
Ethnicity				
Mestizo/White, n (%)	9875 (95.8%)	8790 (96.3%)	1085 (91.8%)	<0.001
Indigenous, n (%)	381 (3.7%)	311 (3.4%)	70 (5.9%)	<0.001
Black, n (%)	49 (0.5%)	23 (0.2%)	26 (2.2%)	<0.001
Location				0.005
Rural Community, n (%)	10199 (98.9%)	9021 (98.9%)	1178 (99.7%)	
Urban Community, n (%)	106 (1%)	103 (1.1%)	3 (0.2%)	
Mortality, n (%)	1961 (19%)	1809 (19.8%)	152 (12.8%)	<0.001

SOURCE: Authors.

**TABLE 2.** Mortality per year.

Year	Total (n=10,306)	Mortality (n=1,960)
2002	631	142 (22.5%)
2003	758	177 (23.3%)
2004	898	202 (22.5%)
2005	1,174	289 (24.6%)
2006	1,228	241 (19.6%)
2007	978	216 (22.1%)
2008	852	172 (29.1%)
2009	771	127 (16.5%)
2010	679	58 (8.5%)
2011	566	98 (17.3%)
2012	589	87 (14.8%)
2013	420	45 (10.7%)
2014	292	42 (14.4%)
2015	222	32 (14.4%)
2016	89	14 (15.7%)
2017	57	7 (12.2%)
2018	101	12 (11.8%)

SOURCE: Authors.

p<0.001) and black individuals (war period: 23 [0.2%] vs. peace period: 26 [2.2%]; p=0.001) injured during the negotiation period. Most of the individuals (98.9%) were injured in rural areas; however, there was a significant reduction in the number of individuals injured in urban areas during the negotiations period (war period: 103 [1.1%] vs. peace period: 3 [0.2%]; p=0.005).

As shown in [Table 2](#), cases and mortality gradually decreased during the peace period. Nevertheless, this trend was evident long before the beginning of the peace negotiations. Mortality was significantly higher during the war period (war period: 1809 [19.8%] vs. peace period: 151 [12.8%]; p<0.001).

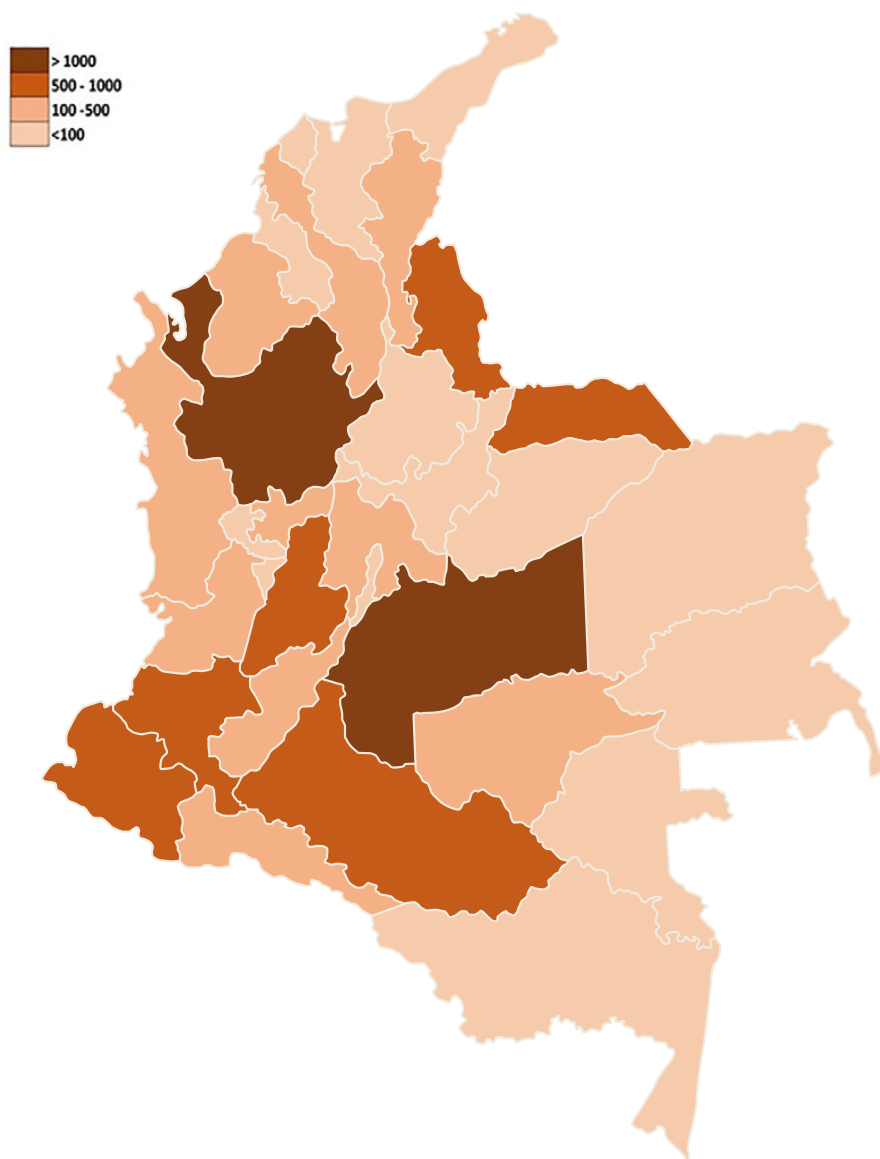
When grouping individuals by geographic areas (departments) ([Figure 1](#)) based on case-volume, mortality was significantly lower in departments with higher landmine injuries (p<0.001). As shown in [Table 3](#), mortality in departments with less than 100 cases for the entire period 28% (n=162/573). Departments with 100 to 500 cases had a mortality of 19.7% (n=437/2208), and those with 500 to 1000 cases had a mortality of 20% (n=846/4211). In contrast, mortality in departments with more than 1000 cases for the entire period 15.6% (n=516/3313), and these differences were statistically significant (p<0.001).

Multivariate regression analysis adjusted by sex, age group (<18y), race, active duty soldier status, rural area, and geographic areas based on case-volume showed that the period of peace negotiations was associated with lower risk –adjusted odds of death (OR= 0.63, 95% CI, 0.5-0.7; p<0.001) ([Table 4](#)).

## DISCUSSION

Using prospectively collected data from the MAP/MUSE Colombian database, an adjusted association was found between the peace negotiations period and a lower likelihood of death among victims of anti-

**FIGURE 1.** Map of Colombia showing the number of cases (case-volume) per Department (geographic areas).



>1000: More than 1000 cases; 500-1000: Five-hundred to one-thousand cases; 100-500: One-hundred to five-hundred cases; <100: Less than one-hundred cases.

**SOURCE:** Authors.

**TABLE 3.** Mortality by Department (geographical areas) case-volume (Cases for the entire period).

	Departments with less than 100 cases	Departments with 100 to 500 cases	Departments with 500 to 1000 cases	Departments with more than 1000 cases	p-value
Mortality, n (%)	162/573 (28%)	437/2208 (19.7%)	846/4211 (20%)	516/3313 (15.6%)	<0.001

**SOURCE:** Authors.

**TABLE 4.** Regresión logística para mortalidad.

	Adjusted OR (95% CI)	p-value
Exposure of primary interest		
Peace negotiations period	0.63 (0.51-0.78)	<0.001
Covariates not of primary interest		
Gender (females)	0.72 (0.55-0.94)	0.01
Age group (Under 18y)	1.14 (0.94-1.38)	0.1
Race (Blacks/Indigenous)	2.12 (1.68-2.68)	<0.001
Soldiers	1.26 (1.11-1.42)	<0.001
Rural Areas	0.95 (0.59-1.55)	0.8
High volume regions (>1000 cases)	0.76 (0.68-0.85)	<0.001
Very low volume regions (<500 cases)	1.58 (1.30-1.92)	<0.001

**CI:** Confidence interval **SOURCE:** Authors.

personnel landmines in Colombia. To our knowledge, this is the first study showing that the period of peace negotiations may have had a positive effect on the outcomes of landmine injured individuals. Thus, our results further support the idea of the potential beneficial effects of seeking peace in regions affected by long-standing conflicts (11,12) such as the Colombian one.

This study showed that adjusted-odds of mortality was lower in patients injured during the peace negotiations period. This might be explained by the assumption that individuals injured during this period received improved pre-hospital care as a result of shorter transport times. Extraction and transportation from “peaceful combat” arenas could be assumed to happen faster due to the lack of delays caused by ongoing combats. Data from previous studies suggest that longer transport times are

associated with poor outcomes among severe blunt trauma patients (13,14). For example, Maddry et al. (14) showed that decreased transport time from the point of injury to a treatment facility was associated with higher survival in patients who suffered a combination of amputation injury and shock. Transport times in hostile settings are influenced by environmental factors and the capability of landing and extracting patients in combat locations (15). It is possible that, during war, injured patients experienced delayed transport times from the point of injury as a result of active hostile fire, which in turn could delay efficient extraction, thus impacting mortality. In contrast, peaceful combat arenas during peace negotiation periods could have the opposite effect by allowing rapid evacuation to medical treatment facilities with the right capabilities to provide advanced life-saving surgical care.

Consistent with previous descriptions (1,2), this research found that the number of anti-personnel landmine victims gradually decreased during the peace negotiations period. A recent single-center analysis of soldiers wounded in combat during the negotiation of the Colombian peace process found a considerable decline in emergency department admissions of hostile casualties during the peace negotiation period in the Colombian southwest (2). Furthermore, they found that damage control surgery and resuscitation procedures also decreased during the same period. Although it is plausible to suggest a strong relationship between the negotiations period (where a truce was established) and fewer casualties, the trend observed in our study came from long before the beginning of the comprehensive process of peace. Therefore, a formal causal inference regarding the time of peace negotiations and the absolute reduction in the number of anti-personnel landmine victims is not possible.

Stratification by geographic areas (departments) based on case-volume showed that mortality was significantly lower in areas with increasing patient volumes. This result seems to be consistent with research from trauma surgery and other disciplines, which found that increasing case-volume is supposed to reduce adverse outcomes (16–18). Based on this assumption, it is believed that higher patient volumes will lead to better organizational structures, more experienced surgical teams, and more efficient decision-making approaches, with this experience resulting in better patient care and outcomes (16–18). For example, Nathens et al. (19) showed that hospitals with a volume of over 650 severe trauma cases per year demonstrated lower risk-adjusted odds of mortality in severely injured patients. It is, therefore, possible that in geographic areas with higher cases, military doctors had more experience in patient extraction, better facilities and more experienced trauma and orthopedic surgeons caring for soldiers wounded in the field.

Our study is not without limitations, and results should be interpreted in the context of the study design and data source used. First, because our primary assumption was that a relationship between peace and mortality exists, we aimed to model the odds of this outcome based on the plausible effect of peace. In these circumstances, the assumption that covariate effects can be interpreted in the same way as the exposure of primary interest could lead to wrong interpretations of the net of all associations concerning the plausible relationship explored (20). Second, we used a government-sponsored database where the available information is limited, increasing the risk of unmeasured confounders. Indeed, results could be biased due to the use of an administrative database like MAP/MUSE because of lack of data granularity (i.e., information

about when deaths occurred, where they occurred, and in-hospital patient variables) to allow for risk adjustment. Third, although the MAP/MUSE database is excellence-certified in data collection and data storage, it is possible that cases from remote regions with difficult access may not have been registered, which in turn could underestimate the burden of the nationwide anti-personnel landmine phenomenon, introducing selection bias in the analysis.

Finally, the relationship between the peace negotiations period and a lower likelihood of mortality could be attributed to time-varying exposures such as indications for damage control surgery, transfusion goals, amounts of fluid resuscitation, and antifibrinolytic therapy for hemorrhage control (21–23). All these therapeutic strategies suffered changes and improvements during the observation period and could have contributed to the association observed. Nevertheless, our hypothesis is rational, plausible, and in line with previous research, which found a positive effect of peace on population health. Thus, we believe that even if we had access to time-varying confounders, peace would have remained associated with lower risk-adjusted odds of mortality.

Despite our limitations, our findings are important to advance the understanding of the peace-health relationship and inform policy-makers in conflict areas about the potential beneficial effects of seeking peace. Furthermore, these results should underpin efforts for an often-overlooked worthwhile endeavor: the pursuit of peace.

Our findings suggest an association between the period of peace negotiations and a lower likelihood of mortality among victims of anti-personnel landmines. Although we cannot establish a strong causal relationship between peace and lower odds of mortality, these results should inform policy-makers about the potentially beneficial effects of peace on individual health outcomes, and should not be misinterpreted or used for political ends.

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### Authors' contribution

**RMN and AFG** conceived the idea.

**MPN, JER, AGZ and DVM** assisted with data preparation.

**RMN and DM** performed the statistical analysis.

All authors provided input to the first draft during brainstorming sessions. All authors wrote the report, made critical revisions to the manuscript, and approved the final version for submission.

### Assistance with the study

None declared.

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### Conflict of Interest

None declared.

### Presentations

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In loving memories of Daniela Rojas-Muñoz.

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