Grouping of body areas affected in traffic accidents. A cohort study

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ABSTRACT

Background: Traffic accidents are considered a public health problem and, according to the World Health Organization, currently is the eighth cause of death in the world. Specifically, pedestrians, cyclists and motorcyclists contribute half of the fatalities. Adequate clinical management in accordance with aggregation patterns of the body areas involved, as well as the characteristics of the accident, will help to reduce mortality and disability in this population.

Methods: Secondary data analysis of a cohort of patients involved in traffic accidents and admitted to the emergency room (ER) of a high complexity hospital in Medellín, Colombia. They were over 15 years of age, had two or more injuries in different areas of the body and had a hospital stay of more than 24 h after admission. A cluster analysis was performed, using Ward's method and the *linfinity* similarity measure, to obtain clusters of body areas most commonly affected depending on the type of vehicle and the type of victim.

Results: Among 2445 patients with traffic accidents, 34% (n = 836) were admitted into the Intensive Care Unit (ICU) and the overall hospital mortality rate was 8% (n = 201). More than 50% of the patients were motorcycle riders but mortality was higher in pedestrian-car accidents (16%, n = 34). The clusters show efficient performance to separate the population depending on the severity of their injuries. Pedestrians had the highest mortality after having accidents with cars and they also had the highest number of body parts clustered, mainly on head and abdomen areas.

Conclusions: Exploring the cluster patterns of injuries and body areas affected in traffic accidents allow to establish anatomical groups defined by the type of accident and the type of vehicle. This classification system will accelerate and prioritize ER-care for these population groups, helping to provide better health care services and to rationalize available resources.

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1. Introduction

Since 1974, the General Assembly of the World Health Organization (WHO) adopted resolution WHA27.59 to declare traffic accidents as a severe public health problem.¹ According to the WHO, every year traffic accidents cause 1.20 million fatalities

in the world. This was mainly in the age group ranging from 15 to 29 years. From 20 to 50 million people sustain non-fatal injuries and a significant proportion of these will have some sort of remaining disability. Ninety one percent of traffic-related deaths were in low and middle-income countries, which despite being a vast majority barely have half of the vehicles registered in the entire world.^{2,3} The WHO estimates that for 2028 traffic accidents will cause 1.8 million fatalities a year.² Currently, traffic accidents are the eighth cause of death in the world, and it is foreseen that for 2030, they will become the fifth.⁴

Africa is the region that has the highest traffic-related mortality rate, 24.1 fatalities per 100,000 inhabitants, and Europe has the lowest, 10.3 fatalities per 100,000 inhabitants.⁴ According to the Basic Health Indicator report in the Americas for 2012, Latin

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America reported a 17.6 mortality rate per 100,000 inhabitants and Colombia reported a 17.9 mortality rate.⁵

Half of the people that die in traffic accidents in all the world are pedestrians, cyclists and motorcyclists which are known as vulnerable users². In Colombia in 2013, the Institute of legal medicine received 48,042 reports of cases of traffic accidents in which there were 6219 fatalities, most of them motorcycle related (44.3%) and pedestrians (29.3%).⁶

From an anatomic perspective and in reference to the kinematics of the trauma, it should be possible to characterize the injuries sustained in traffic accidents in accordance with the type of vehicle (automobile, motorcycle, others) and the type of victim (driver, passenger, pedestrian). This would be a great help in starting to provide medical care because prior knowledge focuses on the more affected body area, according to the nature of the accident and the type of victim, would help to perform more accurate management which would reduce mortality and disability. In the literature, all of the studies that were reviewed presented their information separately depending on the type of victim (driver, passenger or pedestrian) and reported small sample sizes. Leong et al., found in a group of 682 patients that young passengers, representing 14% of the total, have the highest mortality rate and contributed significantly to the death rate among young motorcycle casualties.⁷ Kui et al. conducted a study with 109 pedestrians, where they found pedestrians hit by a minibus had a high proportion of head, chest, and extremity injuries with 84.4%, 50.5%, and 52.3%, respectively.⁸ On the other hand, Nathens et al. found that ten years following initial trauma system implementation, mortality due to traffic crashes began to decline, mainly because of the development of prehospital triage criteria, interfacility transfer protocols and quality assurance.⁹

Therefore, it would be very useful to construct clusters of simple anatomic areas, easy to identify and consistent with the type of traffic accident victim, with a bigger sample size that the reported in literature. Whence our aim was to explore the aggregation patterns of injuries and the zones of the body affected in traffic accidents and establish, using cluster analysis, possible combinations according to the type of vehicle and the type of victim.

2. Methods

2.1. Design

a secondary data analysis was conducted on a bi-directional cohort of patients treated from January 2007 to August 2015 at a high complexity hospital in the city. For the retrospective cohort, we reviewed the electronic clinical records of the patients admitted to the ER from January 1, 2007 and October 31, 2013. For the prospective cohort, we reviewed the electronic clinical records of the patients admitted to the ER from November 1, 2013 to July 31, 2015.

2.2. Participants

patients were designated eligible if they were over 15 years of age, had two or more injuries in different areas of the body (1. Head/neck/cervical spine, 2. Face, 3. Thorax/thoracic spine, 4. Abdomen/lumbar spine, 5. Limbs/Pelvis, 6. External areas) and a hospital stay of more than 24 h after being admitted to the ER. Patients having injuries resulting from an event which was not a traffic accident were excluded, as well as those patients who had already participated in the study. The study was approved by the Ethics Committee of the Medical Research Institute of the School of Medicine at Universidad de Antioquia (Medellín) and the participating hospital.

2.3. Data source

retrospective data were reviewed using electronic clinical records based on a report issued by the information management department. This report was constructed based on five corporal areas from the ICD-10 diagnostic codes: face S02; head and neck S02, S06, S09, S10 and S19; thorax, S20 to S29; abdomen S30 a S39; limbs S42, S72, S73, S75, S78, S82, S83, S85 and S88. In addition, the report also considered patients with general trauma codes (T01 to T07) and war or blast code Y36. For prospective data, there was a trained nurse in charge of patient recruitment and follow-up during hospitalization. The data collected included clinical, demographic and trauma-related characteristics; a description of the different injuries a patient sustained, trauma scoring and body areas affected; the need to be admitted to the ICU, mechanical ventilation, hospital stay and hospital mortality. The entire process from admission, data collection, follow-up and the classification of injuries was confirmed by a qualified trauma-related experienced co-researcher assigned weekly to the study. Case report forms (CRF) were delivered to the Data Coordinating Center (DCC) weekly to verify data clarity and consistency. Any error or lack of information meant returning the CRF to the assistant to review it with the co-researcher in charge. The severity of patients' injuries were classified in accordance with ISS (Injury Severity Score),¹⁰ NISS (New Injury Severity Score),¹¹ RTS (Revised Trauma Score)¹² and TRISS (Trauma and Injury Severity Score).¹³

Table 1
General characteristics of study population.

	n = 2445
Age (mean ± SD), years	36 ± 16
Male	1973 (81%)
Referred	711 (29%)
Accident Variables	
Type of Victim	
Driver	1449 (59%)
Passenger	439 (18%)
Pedestrian	557 (23%)
Type of Vehicle	
Automobile	414 (17%)
Motorcycle	1942 (79%)
Others ^a	89 (4%)
Clinical Variables	
Systolic BP, mm Hg	125 (113–140)
Heart rate, beats/min	88 (78–100)
Respiratory rate, breaths/min	18 (16–20)
Glasgow coma scale	15 (12–15)
Lactate, mmol/L (n = 1061)	2.7 (1.7–3.9)
PT, secs (n = 1152)	12.4 (11.4–13.8)
Scores	
ISS	13 (9–21)
NISS	17 (11–27)
RTS	7.84 (6.90–7.84)
TRISS	4.47 (2.98–5.05)
Outcomes	
Admitted to the ICU	836 (34%)
Mechanical ventilation	746 (31%)
Length of hospital stay, days	6 (3–15)
Hospital mortality rate	201 (8%)

Continuous variables are presented as medians (IQR), unless otherwise indicated. PT: prothrombin time, ISS: injury severity score, NISS: new injury severity score, RTS: revised trauma score, TRISS: trauma revised and injury severity score, ICU: intensive care unit.

^a Others: includes bicycle riders, skaters and skateboards.

Table 2

Patient distribution and mortality depending on type of vehicle and victim.

Type of Victim/Type of Vehicle	Automobile	Motorcycle	Others	P-value	Total
Driver Mortality ^a	69 (2.8%) 4 (6%)	1303 (53.3%) 80 (6%)	77 (3.2%) 6 (8%)	0.834	1449 (59%) 90 (6%)
Passenger Mortality ^a	128 (5.2%) 17 (13%)	307 (12.6%) 29 (9%)	4 (0.2%) –	0.389	439 (18%) 46 (10%)
Pedestrian Mortality ^a	217 (8.9%) 34 (16%)	332 (13.6%) 31 (9%)	8 (0.3%) –	0.046	557 (23%) 65 (12%)
Total Mortality ^a	414 (17%) 55 (13%)	1942 (79%) 140 (7%)	89 (4%) 6 (7%)	<0.001	2445 (100%) 201 (8%)

^a Mortality rate corresponds to each subgroup (cell).

2.4. Outcomes

the primary outcome was the clinical clustering of anatomic areas affected in accordance with the type of vehicle (automobile, motorcycle, and others like bicycles, skateboards and skates) and the type of victim (driver, passenger, pedestrian) at the time of a traffic accident. The AIS (Abbreviated Injury Scale)¹⁴ score was used for this clustering, for it was developed to classify injuries depending on body type, region of the body and severity. This is a tool which includes more than 2000 diagnostics, designated depending on the 6 areas of the body mentioned above. A number from 1 to 6 was assigned to each injury in which one corresponds to a minor injury, 5 to a critical injury and 6 to an untreatable fatal injury (in our study there was no report of any injury scored 6). For

cluster formation, a process of weighing was first conducted based on generating 30 variables which resulted from combining the six anatomic areas described above in a score from 1 to 5 indicating injury severity. Therefore, 100% of the human body was considered, and each one of the six areas potentially compromised were assigned 16.6%. Later, the number of traumas a patient had in just one anatomic area were quantified dividing proportionally the value assigned to each area of the body. Thus, in the same example, if a person had 5 head injuries and three of these had AIS scores of 2, 1 had an AIS score of 4, and 1 had an AIS score of 5, the percentages assigned to each type of injury were 10%, 3.3% and 3.3%, respectively, totaling 16.6% which is what was contemplated for the head area. This way, the sum of the 30 variables should be 100%.

Fig. 1. Cluster of affected body areas depending on type of vehicle (automobile, motorcycle, others) and type of victim (driver, passenger, pedestrian).

A = MOTORCYCLE RIDER
 B = PEDESTRIAN AND MOTORCYCLE
 C = MOTORCYCLE PASSENGER
 D = PEDESTRIAN AND AUTOMOBILE

2.5. Sample size

there was no estimate of the sample size because this study accessed all the information available. The database was saved in Access (Microsoft Office; Microsoft Inc., Redmond, WA) and a statistical analysis was conducted using STATA (release 14; Stata Corp, College Station, TX).

2.6. Statistical analysis

we presented continuous variables with means and standard deviation or medians and interquartile ranks according to their distribution, and categorical variables as proportions. To set up the clinical clusters of the compromised areas that were most similar and homogeneous, we used an exploratory multivariate cluster analysis. This method enables researchers to divide the population in groups with high internal homogeneity (internal cohesion) and high external heterogeneity (external isolation). The process started with the conglomerate of 30 variables and using Ward's method and *linfinity* similarity measure, we obtained clusters of the area's most commonly compromised depending on the type of vehicle and victim. The Ward's method is a hierarchical procedure to find in each step those clusters which joined together would provide less increase in the total sum of errors and in this way the determination of the grouping levels; and the *linfinity* similarity measure is the distance between two points as the sum of absolute differences between their coordinates or the union of horizontal segments and vertical between points. By a visual inspection of the dendrogram, no area was left far behind the others. Dendrograms

graphically present the information concerning which variables are grouped together at various levels of (dis)similarity. At the bottom of the dendrogram, each variable is considered its own cluster. Vertical lines extend up for each variable, and at various (dis)similarity values, these lines are connected to the lines from other variables with a horizontal line. The variables continue to combine until, at the top of the dendrogram, all variables are grouped together. The height of the vertical lines and the range of the (dis)similarity axis give visual clues about the strength of the clustering. Long vertical lines at the top of the dendrogram indicate that the groups represented by those lines are well separated from one another. Shorter lines indicate groups that are not as distinct. Finally, as a sensitivity analysis, the clusters were compared using the chi-square test and Kruskal-Wallis, depending on the nature of the variables, and *p*-values <0.05 were considered statistically significant.

3. Results

During the study 4085 patients were admitted, and of these 2445 corresponded to traffic accident traumas, the others were excluded by: injuries by fire-arm (*n*=557), injuries by knives and blade weapons (*n*=231), Non-vehicular trauma (*n*=134), land-mines (*n*=189), crushing (*n*=32), fall (*n*=432), others (*n*=65). The mean age was 36 years (SD = 16), and 81% (*n*=1973) were male. ISS, NISS, RTS and TRISS medians were 13 (RIQ=9–21), 17 (RIQ=11–27), 7,84 (RIQ=6,90–7,84) and 4,47 (RIQ=2,98–5,05), respectively. Thirty four percent (*n*=836) of the patients were admitted into the ICU, and mortality rate was 8% (*n*=201) (Table 1.)

Fig. 2. Mortality according to clustering on the main combination of vehicles and victims.

Patient distribution depending on the type of transportation, type of victim and their mortality is shown in Table 2. More than 50% of the patients were motorcycle riders; nevertheless, mortality was higher in pedestrian-car accidents (16%, $n=34$).

Fig. 1 presents in dendrograms the clusters constructed for the four principal groups of individuals depending on the type of vehicle and the type of victim. It is noteworthy that for pedestrians that sustain car accidents (Part D), who have the highest mortality, there is a greatest number of body areas clustered, principally the head and the abdomen. According to this clustering, there was a higher mortality rate for motorcycle rider and passengers in cluster 1, whereas motorcycle or automobile pedestrians deaths were more frequent in cluster 2 (Fig. 2). Table 3 and Fig. 3 present a comparison of the different variable combinations that determine

patients' severity in accordance with the clusters produced in the dendrograms. For instance, for motorcycle riders it is possible to identify two clusters of high severity and the worst prognostic: Cluster 1 with slight injuries scored 1 and severe head injury scored 5, along with slight injuries 1 and severe thorax injuries 4; and Cluster 2 with moderate face injuries scored 3 and critical thorax injuries scored 5. Almost all the comparisons (except mortality in pedestrian that sustained motorcycles accidents and length of stay of pedestrians who sustained accidents with vehicles) showed statistically significant differences, suggesting that the differences between the groups maximize as the differences within them minimized. Consequently, these findings are in consonance with the robustness and efficiency of the obtained clusters.

Table 3

Severity scores and outcome variables according to clustering on the main combination of vehicles and victims.

MOTORCYCLE RIDER (A)				
Variables	Cluster 1; $n=149$ (11%); (Head 1 and 5, Thorax 1 and 4)	Cluster 2; $n=14$ (1%); (Face 3 and Thorax 5)	Cluster 3; $n=1140$ (87%); All other areas of the body	P-value
ISS Score	29 (17–33)	29 (22–35)	10 (6–17)	<0.001
NISS Score	34 (22–43)	36 (27–43)	17 (10–24)	<0.001
RTS Score	5.97 (4.74–7.84)	6.90 (5.97–7.84)	7.84 (7.11–7.84)	<0.001
TRISS Score	2.14 (0.60–4.13)	2.97 (1.63–3.54)	4.89 (3.84–5.14)	<0.001
Admitted to the ICU	103 (69%)	14 (100%)	326 (29%)	<0.001
Mechanical ventilation	101 (68%)	10 (71%)	287 (25%)	<0.001
Length of stay, days	8 (3–21)	18 (9–34)	6 (3–14)	0.016
Mortality	43 (29%)	2 (14%)	35 (3%)	<0.001
PEDESTRIAN AND MOTORCYCLE (B)				
	$n=267$ (80%); All other areas of the body	$n=19$ (6%); (External 3, 5, Face 4, Abdomen 1, Thorax 4, Limb 5)	$n=46$ (14%); (Thorax 1, 3, abdomen 5)	P-value
ISS score	10 (9–17)	30 (22–34)	22 (14–29)	<0.001
NISS Score	17 (10–27)	34 (33–41)	27 (21–34)	<0.001
RTS Score	7.84 (7.11–7.84)	6.90 (6.37–7.84)	7.84 (5.97–7.84)	0.001
TRISS Score	3.39 (2.73–5.05)	1.64 (0.79–3.13)	2.42 (0.38–3.20)	<0.001
Admitted to the ICU	80 (30%)	15 (79%)	27 (59%)	<0.001
Mechanical ventilation	70 (26%)	14 (74%)	25 (54%)	<0.001
Length of stay, days	6 (3–11)	28 (11–38)	14 (6–27)	<0.001
Mortality	22 (8%)	4 (21%)	5 (11%)	0.166
MOTORCYCLE PASSENGER (C)				
	$n=57$ (19%); (Head 1 and 4, Thorax 4 and Limb 5)	$n=12$ (4%); (Face 3, Thorax 5, External 3, Abdomen 5 and Limb 4)	$n=238$ (77%); All other areas of the body	P-value
ISS score	26 (18–30)	27 (22–32)	10 (5–14)	<0.001
NISS Score	34 (34–43)	31 (28–44)	14 (9–22)	<0.001
RTS Score	5.97 (5.03–7.84)	7.84 (7.84–7.84)	7.84 (7.84–7.84)	<0.001
TRISS Score	2.29 (1.32–3.42)	3.43 (2.46–3.88)	5.05 (4.30–5.22)	<0.001
Admitted to the ICU	41 (72%)	3 (25%)	42 (18%)	<0.001
Mechanical ventilation	38 (67%)	3 (25%)	34 (14%)	<0.001
Length of stay, days	10 (4–31)	16 (12–21)	5 (3–10)	<0.001
Mortality	15 (26%)	–	14 (6%)	<0.001
PEDESTRIAN AND AUTOMOBILE (D)				
	$n=33$ (15%); (Head 1, Face 2, Thorax 4 and External 3)	$n=52$ (24%); (Head 4 and 5, Face 3, Abdomen 5, 1 and 4, Thorax 5 and External 2)	$n=132$ (61%); All other areas of the body	P-value
ISS score	17 (14–24)	28 (21–35)	10 (5–17)	<0.001
NISS Score	22 (17–29)	41 (31–47)	14 (9–22)	<0.001
RTS Score	7.84 (6.90–7.84)	5.97 (4.59–7.84)	7.84 (6.90–7.84)	<0.001
TRISS Score	3.39 (2.14–4.05)	1.26 (0.41–2.54)	4.02 (3.14–5.05)	<0.001
Admitted to the ICU	12 (36%)	42 (81%)	38 (29%)	<0.001
Mechanical ventilation	10 (30%)	38 (73%)	34 (26%)	<0.001
Length of stay, days	4 (3–17)	10 (3–32)	8 (4–15)	0.521
Mortality	3 (9%)	22 (42%)	9 (7%)	<0.001

Fig. 3. Severity scores according to clustering on the main combination of vehicles and victims.

4. Discussion

In our study population, the clusters constructed to identify the main affected areas of the body showed efficient performance separating the population based on severity. The clusters for motorcycle drivers show a clear grouping for six body areas involving head with thorax and face with thorax. On the other hand, clusters for people who suffer accidents with motorcycles but as passengers or pedestrians each identify nine body areas with different combinations including head, face, abdomen, limb, thorax and external. The clustering was more noticeable on pedestrians that suffered accidents with automobiles, who also had the highest mortality with severe head, thorax and abdomen traumas. These findings are consistent with what the WHO reported: that half the people who die in traffic accidents correspond to the “vulnerable users on public roads”.² Motorcyclists are also included among vulnerable users, and their mortality rates were 9% for motorcycle passengers and 6% for motorcycle riders. This mortality rate for motorcycle users was lower than the one found in Singapore by Leong and researchers, with the mortality rate among young passengers of 29.2% versus 9.7% for riders.⁷

Kui et al., conducted a study to determine the injuries and risk patterns for pedestrians who sustained accidents with automobiles in China.⁸ They reported a mean age of 56 ± 16 years and a high proportion of head, thorax and limb injuries. This information agrees with our findings in which the clusters constructed also have high head and thorax scores. Unlike the above, our population's mean age was lower and the abdomen was an

essential part of several clusters, in particular those related to pedestrians' conditions. These combinations of areas explained a higher mortality rate in this group of people, for there is a clear association between the highest scores of affected areas and higher severity. On the other hand, relevant literature on injury reports the main areas compromised as those presented in our clusters for this type of victims, notwithstanding the type of vehicle involved in the accident.^{8,15–17}

For motorcycle riders, our study produced 2 relevant clusters. The first one is formed by face scored 3 and thorax scored 5. This means that these motorcycle riders most commonly sustained injuries penetrating their faces with a blood-loss volume of more than 20%, lacerations, avulsions and fractures, along with myocardial contusion, pulmonary contusion and hemo-pneumo-thorax. The second cluster consists of head 1 and 5 and thorax 1 and 4, and this means the compromised areas of the body range from superficial injuries on the scalp to ischemic cerebral injuries and prolonged traumatic comas. Hang-Tsung et al. compared injury patterns, severity, mortality rates and hospital stays of patients with injuries resulting from motorcycle accidents. Even though their main interest was to identify differences depending on patients' condition of obesity, they also reported higher rates compromising the thorax and face.¹⁸ This finding, which is probably explained by motorcycle riders and passengers' great physical exposure and the absence of required regulation protection gear, supports our clusters' excellent performance. On the other hand, specifically for motorcycle passengers, the areas of the body closest within the first cluster were head 1 and 4, thorax 4 and limb injuries 5; and for the second cluster the areas were face

3, thorax 5, external body 3, abdomen 5 and limb injuries 4. Zhao et al. compared injuries sustained by motorcycle riders with the ones sustained by their passengers, and they found that for the latter, the most compromised was the head with an AIS of 4 or more, and the thorax and lower limbs had an AIS of 2 or 3.¹⁹ The above results agree with our findings, although our clusters exhibited higher severity in areas as the thorax and limbs, in addition to a more frequently affected abdomen. Fitzharris et al., found that motorcycle passengers were more prone to sustaining injuries resulting from the crushing of their lower limbs in comparison with motorcycle riders.²⁰ These results are seen reflected in our clusters in which motorcycle passengers had affected limbs with an AIS of 4 and 5.

We acknowledge some limitations. First, we considered only hospital admissions and do not account for trauma deaths that occur prior to reaching hospital. Similarly, the place of the study is a high complexity hospital with higher frequency of severe cases and ignoring those managed at smaller healthcare setups. Such a different injury patterns can influence the conclusions derived from our study. Second, the transportability of our results to other countries given the epidemiological characteristics of Medellín should be noted, as our findings are probably more important to low and middle-income countries where motorized two wheeled vehicles are more frequent. Finally, this type of analysis is highly dependent on the clustering method implemented. Therefore, there is a non-quantifiable component of subjectivity in the model and, consequently, also in its findings. We did not find any studies with similar characteristics to ours, because all of the investigations reviewed presented their information separately depending on the type of victim as driver, passenger or pedestrian, which hinders the comparison and the analysis of the results. Although this is a secondary analysis of a cohort collected for purposes different from constructing clusters of the affected areas of the body, it is a strength because there was no information bias when collecting data related to trauma depending on the type of vehicle or type of victim. Furthermore, the sample size and the construction of profiles in accordance with specific trauma groups is a strength, because the literature reports studies having smaller sample sizes and only particular types of victims. On the other hand, the graphic representation of the compromised areas depending on type of victims simplifies and streamlines the identification that healthcare personnel must perform in providing medical treatment.

We constructed clusters of simple anatomic areas, easy to identify and consistent with the type of traffic accident victim, which will enable healthcare personnel in charge of the ER to speed up and give priority to these people's treatment. This tool should facilitate providing better service, identifying severity and focusing the health care provided to make a more rational efficient use of hospital resources.

Conflict of interest statement

Alba Luz León, Johana Ascuntar-Tello, Carlos Oliver Valderrama, Nelson Giraldo, Alfredo Constain, Andres Puerta, Camilo Restrepo and Fabián Jaimes declare that they have no conflict of interest.

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Compliance with ethical standards

Not potential conflicts of interest

Research involving Human Participants (The protocol was approved by the ethical committee of the School of Medicine-University of Antioquia and the institutional review board of the HPTU without necessary the informed consent)

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