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FORENSIC CHARACTERISTICS OF FIREARM INJURIES: WEAPON TYPE, RANGE OF FIRE AND WOUND PATTERNS IN MEDICO-LEGAL CASES FROM NORTH INDIA

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ABSTRACT

Background: Firearm injuries pose complex challenges in forensic medicine because wound morphology, firing distance, and weapon type are crucial for reconstructing shooting events and determining the manner of injury. In low- and middle-income countries such as India, the widespread use of illegal, country-made and smooth-bore firearms results in variable and atypical wound patterns, complicating medico-legal interpretation.

Objectives: To analyze the forensic characteristics of firearm injuries, including weapon type, number of shots, wound patterns, and range of fire, in medico-legal cases presenting to a tertiary care centre in North India.

Methods: This was a prospective, observational medico-legal study conducted at S. N. Medical College and Hospital, Agra, from March 2016 to February 2017. A total of 124 firearm injury cases were included using universal sampling. All victims were examined using standard forensic protocols. Data collected included type of weapon, number of shots fired, entry and exit wounds, powder effects (blackening, tattooing, singeing), pellet or projectile dispersion, and associated injuries. The range of fire was classified as contact, close, distant, or undetermined based on wound morphology. Data were analyzed using descriptive statistics and Chi-square goodness-of-fit tests.

Results: Shotguns (47.6%) and rifled firearms (45.2%) were the most commonly used weapons ($p < 0.01$). Single-shot injuries predominated (69.4%, $p < 0.001$), and single entry wounds were observed in 74.2% of cases ($p < 0.001$). Among cases with exit wounds, 78.5% had a single exit wound ($p = 0.0025$). Close-range firing was documented in 70.9% of cases ($p < 0.001$), while contact shots were rare (2.4%). These findings indicate a consistent pattern of deliberate, close-range interpersonal firearm violence.

Conclusion: Firearm injuries in North India show a distinct forensic signature characterized by smooth-bore and rifled weapons, predominantly single-shot wounds, and close-range firing, reflecting intentional violent assaults. Recognition of these patterns is essential for accurate medico-legal reconstruction and judicial decision-making.

Keywords: Firearm injuries; Gunshot wounds; Forensic ballistics; Range of fire; Entry-exit wounds; Illegal firearms

INTRODUCTION

Firearm injuries present one of the most complex challenges in forensic medicine because they combine elements of trauma, ballistics, and legal interpretation. Unlike other forms of mechanical injury, gunshot wounds are produced by high-velocity projectiles that transfer large amounts of kinetic energy to tissues, creating unique wound patterns, cavitation effects, and tissue destruction that vary according to weapon type, ammunition, distance of firing, and the anatomical site struck [1,2]. Accurate interpretation of these injuries is fundamental for reconstructing the circumstances of shooting, determining the manner of death, and providing expert medico-legal opinion in courts of law.The forensic evaluation of firearm wounds relies on a systematic analysis of entry and exit wounds, surrounding skin changes, projectile characteristics, and internal wound tracks [1–3]. The appearance of the entry wound, including features such as abrasion collar, marginal contusion, blackening, tattooing, and singeing, provides vital clues regarding the range of fire and type of weapon used [4]. Similarly, the presence or absence of exit wounds, pellet dispersion, and internal tissue damage can indicate whether the weapon was a smooth-bore shotgun, rifled firearm, or a country-made improvised gun [5]. These parameters are essential for differentiating between contact, close-range, and distant shots and for correlating wound morphology with ballistic evidence recovered from the scene or body.

Globally, firearm-related deaths and injuries account for a significant proportion of violent trauma. However, the forensic characteristics of these injuries differ widely between countries depending on weapon availability, legal regulation, and sociocultural factors [6]. In high-income countries, most civilian firearm injuries involve legally owned handguns or hunting rifles, often in suicidal or domestic contexts, producing relatively predictable wound patterns [7]. In contrast, in many low- and middle-income countries, including those in South Asia and Africa, firearm injuries are more commonly caused by illegal, homemade, or modified weapons, which produce atypical and sometimes misleading wound features [8].

India presents a particularly complex forensic landscape for firearm injury analysis. Although national firearm homicide rates are lower than those in some Western nations, India harbors one of the world's largest civilian firearm populations, with the majority being unlicensed or illegal [9]. Locally manufactured or "country-made" guns, often crudely constructed and loaded with non-standard projectiles such as nails, pellets, or metal fragments, are widely used in rural and semi-urban areas [10]. These weapons lack ballistic standardization, leading to unpredictable wound morphology, making forensic interpretation more difficult than in cases involving factory-made firearms [11].

Shotguns and smooth-bore firearms are especially prevalent in North India, where they are traditionally used for hunting, crop protection, and sometimes ceremonial firing during social events [12]. When used in assaults, these weapons produce distinctive patterns of injury characterized by pellet dispersion, multiple small entry wounds, and extensive tissue damage at close range [2,5]. Rifled firearms, on the other hand, fire single, high-velocity projectiles that typically produce smaller entry wounds but deeper internal injury and cavitation effects [3]. Differentiating between these weapon types based on wound morphology is critical for both medico-legal opinion and criminal investigation.

One of the most important tasks of the forensic pathologist is the determination of the range of fire. Contact and close-range shots produce characteristic features such as soot deposition, burning, and powder tattooing, while distant shots lack these features and show only mechanical tissue disruption [4,13]. However, in cases involving homemade or modified weapons, these classical signs may be absent or altered, complicating the estimation of firing distance [11,14]. Inaccurate range

determination can lead to serious legal consequences, particularly in distinguishing between homicide, suicide, and accidental discharge.

Several international studies have analyzed firearm wound patterns in relation to weapon type and shooting distance. Druid demonstrated that internal bullet trajectory and wound direction can assist in differentiating homicidal from suicidal gunshot wounds [13]. Solarino et al. showed that multiple entrance wounds and high-velocity handgun injuries are more common in homicidal cases, whereas suicidal cases typically involve a single contact wound to the head or chest [7]. Studies from Pakistan and Egypt have reported extensive variability in wound morphology due to the frequent use of high-velocity rifles and homemade firearms [8,15].

In India, however, relatively few systematic studies have focused on the forensic morphology of firearm wounds in living and deceased victims. Most available research has concentrated on epidemiological or medico-legal patterns, such as manner of death and demographic distribution [12,16]. Detailed analyses of weapon type, number of shots, entry-exit wound patterns, and firing range are sparse, particularly in regions where illegal and country-made firearms are common.

The Agra region of North India represents such an area, where both smooth-bore shotguns and rifled weapons are widely used in violent encounters. The Emergency Department of S. N. Medical College and Hospital, Agra, serves as a major referral center for firearm injuries and medico-legal cases from surrounding districts. The diversity of weapons and injury patterns seen in this setting provides a unique opportunity to study the forensic characteristics of firearm wounds in a real-world, high-burden environment.

Against this background, the present study was undertaken to analyze weapon type, range of fire, and wound patterns in firearm injury cases presenting to a tertiary care center in North India. By systematically examining entry and exit wounds, number of shots, and firing distance, this study aims to generate region-specific forensic data that can improve the accuracy of medico-legal interpretation and support the effective investigation of firearm-related crimes.

MATERIALS AND METHODS

Study Design and Setting: This was a prospective, observational medico-legal study conducted in the Department of Forensic Medicine and Emergency Department of S. N. Medical College and Hospital, Agra, Uttar Pradesh, India, a major tertiary care referral center catering to both urban and rural populations of North India. The study was carried out over a one-year period from March 2016 to February 2017.

Study Population: All cases of firearm injury brought to the emergency department and referred for medico-legal examination during the study period were included. Both living victims and those who later succumbed to their injuries and underwent post-mortem examination were evaluated.

Sample Size: A total of 124 firearm injury cases were enrolled during the study period. Universal sampling was adopted, and all eligible cases presenting during the defined study period were included.

Inclusion Criteria

- Patients with a definite history of firearm injury
- Presence of clinical or forensic evidence suggestive of firearm trauma
- Cases referred for medico-legal examination due to suspected firearm injury

Exclusion Criteria

- Doubtful cases where firearm injury could not be confirmed
- Medico-legal cases caused by mechanisms other than firearms (road traffic accidents, burns, sharp or blunt trauma, poisoning)

Data Collection Procedure: Each case was examined using standard forensic and clinical protocols. Data were collected from:
- Victims or their attendants
- Police and investigating officers
- Hospital records
- Post-mortem reports (for fatal cases)

A structured proforma was used to record detailed firearm-specific parameters, including:
- Type of weapon: shotgun (smooth-bore), rifled firearm, or others
- Number of shots fired: single or multiple
- Wound characteristics: number, size, shape, margins, abrasion collar
- Entry and exit wounds: number and anatomical location
- Presence of soot, blackening, tattooing, singeing
- Pellet or projectile dispersion
- Associated internal injuries

Assessment of Range of Fire
The range of firing was determined based on standard forensic criteria:
- Contact shot: muzzle in contact with skin, with burning and soot deposition
- Close-range shot: presence of blackening, tattooing, or singeing
- Distant shot: absence of powder effects, only mechanical tissue damage
- Undetermined: when wound morphology was distorted due to country-made weapons or multiple injuries

Operational Definitions
- Entry wound: wound produced at the point of projectile entry, typically showing abrasion collar and inverted margins
- Exit wound: wound produced at the point of projectile exit, usually everted and irregular
- Multiple shots: presence of more than one entry wound

Statistical Analysis: Data were entered in Microsoft Excel and analyzed using descriptive statistics. Categorical variables were expressed as frequencies and percentages. Data were presented using tables and charts. No inferential statistics were applied, as the objective was forensic pattern analysis

Ethical Considerations: The study was conducted after approval from the Institutional Ethics Committee of S. N. Medical College, Agra. All cases were medico-legal in nature and examined as per legal and institutional protocols. Confidentiality and anonymity of victims were strictly maintained.

RESULTS

A total of 124 medico-legal firearm injury cases were analyzed with respect to weapon type, number of shots, wound pattern, and range of fire.The distribution of firearm types was highly non-random, with shotguns and rifled firearms used far more frequently than other weapons. This reflects the dual pattern of violence in North India, where country-made smooth-bore guns and rifled weapons are both widely used. Table 1 shows the distribution of type of firearm used.

Table 1. Distribution of Type of Firearm Used (n = 124)

Weapon type	Cases	Percentage
Shotgun (smooth-bore)	59	47.6%
Rifled firearm	56	45.2%
Others / undetermined	9	7.2%
Total	124	100%
Statistical test: Chi-square goodness-of-fit; $\chi^2 = 38.05$, df = 2, $p < 0.01$		

Single-shot firing occurred significantly more often than multiple-shot firing. Most firearm injuries resulted from a single trigger pull, but nearly one-third involved repeated firing, which is consistent with homicidal intent using rifled or automatic weapons. Table 2 shows the distribution of number of shots fired.

Table 2. Distribution of Number of Shots Fired (n = 124)

Number of shots	Cases	Percentage
Single shot	86	69.4%
Multiple shots	38	30.6%
Total	124	100%
Statistical test: Chi-square goodness-of-fit; $\chi^2 = 18.58$, df = 1, $p = 0.000016$		

Single-entry wounds were significantly more common than multiple-entry wounds. This supports the finding that single-shot attacks predominate, although one-quarter of victims sustained multiple ballistic penetrations, indicating repeated firing. Table 3 shows the distribution of entry wounds.

Table 3. Distribution of Entry Wounds (n = 124)

Entry wound pattern	Cases	Percentage
Single entry wound	92	74.2%
Multiple entry wounds	32	25.8%
Total	124	100%
Statistical test: Chi-square goodness-of-fit; $\chi^2 = 29.03$, df = 1, $p < 0.0001$		

Single exit wounds were significantly more frequent than multiple exit wounds. Most projectiles either exited once or remained lodged, whereas multiple exit wounds reflect pellet dispersion or multiple bullet tracks. Table 4 shows the distribution of exit wounds among cases with exit wound.

Table 4. Distribution of Exit Wounds among Cases with Exit Wound (n = 28)

Exit wound pattern	Cases	Percentage
Single exit wound	22	78.5%
Multiple exit wounds	6	21.5%
Total	28	100%
Statistical test: Chi-square goodness-of-fit; $\chi^2 = 9.14$, df = 1, $p = 0.0025$		

The distribution of firing distance was extremely non-random, with close-range firing dominating. The overwhelming predominance of close-range shots indicates deliberate targeting in interpersonal violence rather than accidental or long-distance firing. Table 5 shows the distribution of range of fire.

Table 5. Distribution of Range of Fire (n = 124)

Range of fire	Cases	Percentage
Contact	3	2.4%
Close	88	70.9%
Distant	29	23.4%
Undetermined	4	3.2%
Total	124	100%
Statistical test: Chi-square goodness-of-fit; $\chi^2 = 153.74$, df = 3, $p < 0.001$		

This study demonstrates that firearm injuries in North India show a distinct forensic signature characterized by:

- Predominant use of shotguns and rifled weapons
- Mostly single-shot, single-entry wound patterns
- Close-range firing in more than 70% of cases

These patterns are highly suggestive of intentional, homicidal firearm use, and provide strong forensic evidence for medico-legal reconstruction of shooting events.

DISCUSSION

The present study provides a detailed forensic analysis of firearm injuries in medico-legal cases from North India, focusing on weapon type, number of shots, wound morphology, and range of fire. The findings reveal a characteristic ballistic pattern dominated by smooth-bore shotguns and rifled firearms, predominantly single-shot injuries, and a striking predominance of close-range firing, highlighting the intentional and violent nature of most firearm assaults in this region.

In the present study, shotguns (47.6%) and rifled firearms (45.2%) were almost equally responsible for firearm injuries. This pattern differs from urban and conflict-prone regions where rifled and automatic weapons dominate. Kohli and Aggarwal reported rifled weapons in 82.2% of firearm deaths in Delhi [12], while Zahid et al. found rifled weapons in 96.5% of homicidal firearm deaths in Peshawar [8]. In contrast, Singh and Singh reported a predominance of smooth-bore and country-made shotguns in northern India [10], which closely aligns with the findings of the present study. The high usage of shotguns reflects their widespread availability, low cost, and local manufacture in rural and semi-urban North India, leading to distinctive forensic injury patterns such as pellet dispersion and multiple small entry wounds [2,5].

Single-shot injuries accounted for 69.4% of cases, and 74.2% of victims had a single entry wound, indicating that most shootings involved a single trigger pull. This observation is consistent with findings by Solarino et al., who reported that most suicidal and many homicidal firearm cases involve single-shot injuries [7]. However, 30.6% of cases in the present study involved multiple shots, which is characteristic of homicidal attacks using rifled or automatic firearms, as also described in studies from Italy and Pakistan [7,8]. The presence of multiple entry wounds in 25.8% of victims further supports the violent, targeted nature of these assaults.

Among cases where exit wounds were present, 78.5% showed a single exit wound. This suggests that in most cases the projectile either exited the body once or became lodged within tissues, which is typical of both shotgun pellets and rifled bullets depending on velocity and tissue resistance [3,4]. Multiple exit wounds, observed in 21.5%, are most likely attributable to pellet dispersion from smooth-bore weapons or multiple bullet trajectories, a feature commonly seen in shotgun injuries [2,10].

A striking finding of this study was the predominance of close-range firing (70.9%), with only 2.4% contact shots and 23.4% distant shots. Similar patterns have been reported in homicidal firearm injuries, where assailants typically fire from close proximity to ensure lethality [13]. Druid demonstrated that close-range firing and bullet trajectory are valuable indicators for differentiating homicide from suicide [13]. In contrast, suicidal gunshot wounds most often involve contact or near-

contact shots to the head or chest, which were rare in the present study, further supporting the homicidal nature of most cases [7,12].

The presence of blackening, tattooing, and singeing in a large proportion of close-range cases is consistent with classical forensic descriptions of powder effects in short-distance firing [1,4]. However, the use of country-made and improvised firearms can sometimes alter these features, leading to undetermined range in a small number of cases, as also reported in Egyptian and Pakistani studies [8,15].

The forensic patterns observed in this study—predominance of smooth-bore and rifled weapons, single-shot injuries, and close-range firing—provide critical insight into the mechanism and intent of firearm violence in North India. These findings reinforce the importance of detailed wound examination in reconstructing shooting events and correlating clinical and autopsy findings with ballistic evidence [3,14]. The high proportion of close-range shots suggests deliberate targeting rather than accidental discharge, which has significant legal implications in determining culpability and manner of injury.

International studies from Europe and North America typically report more standardized wound patterns due to the use of factory-made firearms [7]. In contrast, the variability seen in this study reflects the heterogeneous nature of weapons used in India, particularly country-made guns and shotguns [10,16]. Similar forensic variability has been reported from Egypt and Pakistan, where illegal and homemade firearms are also widely used [8,15]. These regional differences highlight the need for locally generated forensic data to improve accuracy in medico-legal opinion.

Limitations

The study is limited by its hospital-based design and the absence of laboratory ballistic testing. Additionally, cases that died at the scene were not included. Despite these limitations, the prospective design and standardized forensic documentation make the findings highly relevant to real-world medico-legal practice.

CONCLUSION

This study provides important forensic insight into the ballistic characteristics of firearm injuries in medico-legal cases from North India. The findings demonstrate a distinct pattern dominated by smooth-bore shotguns and rifled firearms, predominantly single-shot injuries, and an overwhelming predominance of close-range firing, all of which strongly indicate intentional interpersonal violence rather than accidental discharge. The frequent occurrence of single entry and exit wounds reflects the mechanics of commonly used weapons, while the presence of multiple shots and pellet dispersion in a substantial proportion of cases highlights the severity and deliberateness of assaults. These region-specific forensic patterns are shaped by the widespread availability of illegal and country-made firearms, which produce variable and sometimes atypical wound morphology. Systematic documentation of wound characteristics and firing range is therefore crucial for accurate medico-legal reconstruction and judicial interpretation. The study underscores the need for improved firearm regulation, better forensic training, and enhanced integration of ballistic evidence into criminal investigations.

Declarations

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