J Neurosurg Spine 14:198–208, 2011

Hangman's fracture: a historical and biomechanical perspective

Historical vignette

Mahmoud Rayes, M.D., Monika Mittal, M.D., Setti S. Rengachary, M.D., and Sandeep Mittal, M.D., F.R.C.S.C.

Department of Neurosurgery, Wayne State University, Detroit, Michigan

The execution technique of hanging, introduced by the Angle, Saxon, and Jute Germanic tribes during their invasions of the Roman Empire and Britain in the 5th century, has remained largely unchanged over time. The earliest form of a gallows was a tree on which prisoners were hanged. Despite the introduction of several modifications such as a trap door, the main mechanism of death remained asphyxiation. This created the opportunity for attempted revival after the execution, and indeed several well-known cases of survival following judicial hanging have been reported. It was not until the introduction of the standard drop by Dr. Samuel Haughton in 1866, and the so-called long drop by William Marwood in 1872 that hanging became a standard, humane means to achieve instantaneous death. Hangmen, however, fearing knot slippage, started substituting the subaural knot for the traditional submental knot. Subaural knots were not as effective, and cases of decapitation were recorded. Standardization of the long drop was further propagated by John Berry, an executioner who used mathematical calculations to estimate the correct drop length for each individual to be hanged. A British committee on capital sentences, led by Lord Aberdare, studied the execution method, and advocated for the submental knot. However, it was not until Frederic Wood-Jones published his seminal work in 1913 that cervical fractures were identified as the main mechanism of death following hanging in which the long drop and a submental knot were used. Schneider introduced the term "hangman's fracture" in 1965, and reported on the biomechanics and other similarities of the cervical fractures seen following judicial hangings and those caused by motor vehicle accidents. *(DOI: 10.3171/2010.10.SPINE09805)*

Key Words • **cervical fracture** • **dislocation fracture** • **hyperextension-distraction injury** • **decapitation** • **traumatic spondylolisthesis of axis** • **execution** • **judicial hanging** • **skull base fracture**

Hanging has been and remains one of the oldest and most commonly used methods of execution. Unfortunately, its application was plagued by technical failures, survivals, and decapitations. However, judicial hanging remained largely unchanged for centuries before meaningful modifications to its process were introduced and applied. In fact, the precise pathophysiological mechanisms leading to death by hanging were not identified until the beginning of the 19th century.

The History of Hanging

The earliest account in history of a formal execution by hanging can be found in the 22nd book of Homer's *Odyssey*. This poem, believed to have been written between 800 and 600 BCE, describes the hanging of 12 household servants by the hero Odysseus and his wife Penelope.[11] However, it was the German tribes (for example, Angles, Saxons, and Jutes) who introduced hanging as a method of execution during their invasions of the Roman Empire and Britain in the 5th century.[5,7,11] Rapidly becoming a popular execution method in Europe, hanging was adopted as a punishment for many crimes, including treason, robbery, murder, and piracy.[5] During his reign, King Henry VIII decreed that 72,000 people be executed by various methods, including hanging (Fig. 1). Judicial hanging was not solely restricted to men; women and children also found themselves in front of the gallows.[5]

Surprisingly, the technique and method of hanging has remained mostly unchanged over the past 15 centuries. The earliest form of gallows was a tree, with prisoners being hauled up manually by the hangman or pulled off a ladder or a wagon. In 1571, the famed "Triple Tree" gallows was installed at Tyburn. This replaced previous smaller structures and remained in use until 1759. Tyburn's Triple Tree consisted of 3 tall posts (approximately 12 feet in length) coupled at the top with beams in a triangular form to provide a triple gallows under which 3 carts could be backed at a time, allowing mass executions (Fig. 2). For

Abbreviation used in this paper: cwt = centrum weight.

Fig. 1. Portrait of Henry VIII, King of England (1491–1547).

Fig. 2. The famous "Triple Tree" at Tyburn. A convict is being hauled up by the hangman from a cart to the Tyburn gallows. (Reproduced from Bailey BJ: **Hangmen of England: A History of Execution from Jack Ketch to Albert Pierrepoint.** London: W. H. Allen, 1989.)

example, on June 23, 1649, 23 men and 1 woman were simultaneously executed for burglary and robbery. At the time, hangings were public events and attracted large, unruly crowds (Fig. 3). The modern expression "gala day" is derived from the Anglo-Saxon "gallows day."

In 1783, judicial hangings were transferred to Newgate prison, where the "New Drop" gallows was developed. Newgate's gallows was a large, boxlike structure (10 feet long by 8 feet wide) with 2 upright posts supporting 2 parallel beams from which a dozen prisoners could be hanged simultaneously (Fig. 4). The New Drop gallows was mounted on wheels and brought out by a team of horses for each hanging. The Newgate model became the norm, and was later copied by several county prisons.

In 1885, Lieutenant Colonel Alton Beamish was commissioned to design a standard gallows for use throughout England. This consisted of 2 uprights with an 8-in crossbeam. The beam was long enough to execute 3 prisoners side by side. The trapdoors were released by a metal lever set into the floor of the execution chamber (Fig. 5). This Victorian design provided greater accuracy and efficiency. The first person to die on the new-style "step-free" gallows was Matthew William Chadwick in 1890, at Kirkdale Prison in Liverpool. However, the precise mechanism and timing of death after hanging were still not clearly known at this time. This was quite evident, as judges had to legally order the convict "to be hanged from the neck *until* dead" (emphasis ours).[5,22] The following is a formal order to execute a convict, addressed to a hangman named James Berry (Fig. 6):[5]

To JAMES BERRY

I_____, of_____, in the County of_____, Esquire, Sheriff of the said County of_____, do hereby authorize you to hang A_____, B_____who now lies under Sentence of Death in her Majesty's Prison at_____.

Dated this_____day of _____

_____, Sheriff

"This is to be folded in three, and endorsed outside,

Re: A_____, B_____

AUTHORITY TO HANG

_____Sheriff

_____shire.

Fig. 3. Rather than being deterred by the spectacle, the morbid excitement and the carnival-like feeling surrounding the hangings attracted large crowds. Up until 1868, all hangings in England were carried out in public.

To ensure death, convicts were left hanging for almost half an hour in some cases, and it was the responsibility of the surgeon on site to declare that the judicial hanging was successful, as determined by absent heart sounds.[5] The following is an example of the official certificate of death, known as "The Last Certificate" provided by the surgeon on site:

> I_____, the Surgeon of His Majesty's Prison of_____, hereby certify that I this day examined the Body of_____, on whom Judgment of Death was this day executed in the said Prison; and that on that examination I found that the said_____was dead.
>
> Dated this_____day of_____.

In London, from 1752 to 1809, the bodies of murderers were transported to Surgeons' Hall and mandated to be publicly dissected.

Difficulties With Hanging

In instances when death was slow in coming, the hangman would intervene by pulling the condemned by the legs, by lifting and jerking the body, or by sitting on the shoulders.[5,22] This added more weight and pressure on the neck to ensure completion of the execution. As expected, there were many occasions in which the execution failed and the executioner had to repeat the process, multiple times if necessary. For example, a convict named John Lee was hanged 3 times in a row on February 23, 1885. None of the attempts was successful; he was later pardoned. Execution failure was caused by either hardware problems or by factors related to the hangman himself. Hardware issues included rope breakage and trapdoor malfunction. There were also reports of unsuccessful executions because the hangman was under the influence of alcohol or did not pay attention to details like the build of the convict's neck or unusual situations like the presence of a tracheostomy (which has been documented in texts such as the *Rig Veda*, an ancient Indian sacred collection of Vedic Sanskrit hymns that first appeared as oral tradition around 4000 BCE).[1,5,22] Another important factor was the absence of clear and scientific guidelines that would ensure accurate, effective, and consistent results.

Furthermore, there were documented cases in which the executed convicts were revived, either at the hanging site, in the anatomy theater, or in the coffin while being transported on a wagon to the graveyard. The roads were generally very rough, and with the absence of shock absorbers, a sort of artificial resuscitation took place during the trip on the wagon, which revived the "deceased" convict.[22] Not uncommonly, the convict's friends and relatives would attempt to resuscitate the condemned with the help of a surgeon as soon as death was pronounced. The surgeon would bleed the convict, and in some instances give spirits and cordials, and those who were revived were either executed again, pardoned, or ran away and started a new life.[5,22]

Surviving the Gallows

An interesting version of this postexecution revival

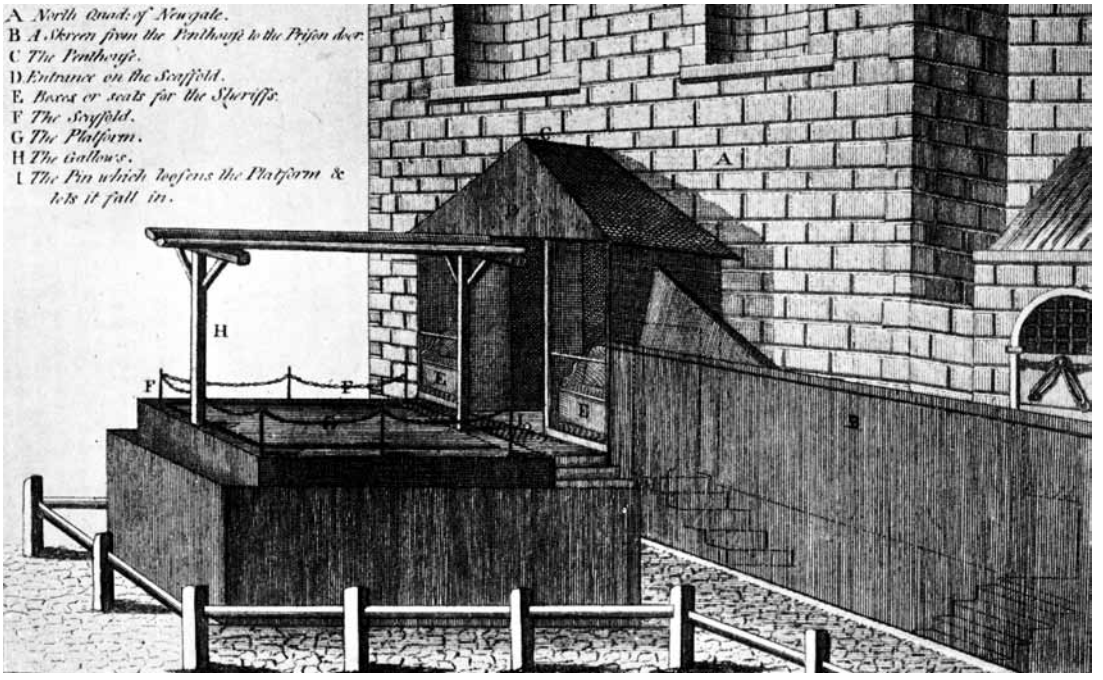

Fig. 4. The New Drop gallows at Newgate in its original form. The first executions were on December 9, 1783, when 9 men and 1 woman were hanged simultaneously for a variety of offenses.

phenomenon took place in Scotland. Margaret Dickson (also known as "Half-Hangit Maggie") was convicted of concealing her pregnancy and was hanged in Edinburgh's Grassmarket on September 2, 1724. The hangman had to drag down her legs to ensure death, and left her hanging for a prolonged period of time. Her friends succeeded in taking her from surgeons who wanted to take the body to anatomists; while accompanying the cart to Musselburgh for burial, they were surprised, as Margaret started showing signs of life. By the time they reached their destination, Dickson was almost fully revived, and people gathered around to see this "miracle." She continued her life and went on to have several children.[22]

Another remarkable survival story was that of Anne Greene, a maid in the house of Sir Thomas Read in Oxfordshire. She was 22 years old when she was probably seduced by Read's grandson and became pregnant. After giving birth to a premature child, she was convicted of killing the boy and was hanged on December 14, 1650 (Fig. 7). The public execution was carried out as usual; she was left hanging for almost half an hour. Her friends tried to ease her agony by pulling her legs down and by lifting her up and jerking her down. After being pronounced dead, she was taken to the home of Dr. William Petty (1623–1687). Petty was the Tomlins Reader in Anatomy at Oxford and a long-standing colleague and mentor of Sir Thomas Willis (1621–1675).[17,21] They often performed dissections together at Petty's residence in Bulkley Hall. When Greene's coffin was opened, she was noted to be breathing, and a strange noise could be heard coming from her throat. Willis and Petty immediately started the process of resuscitation. They poured a hot cordial spirit into her mouth and tickled her throat with a feather to provoke coughing. They rubbed her arms and legs until she opened her eyes, and then bled 5 ounces from her arm. She was kept warm by a "plaister" on her chest and abdomen. Subsequently, Greene was moved to a bed with another woman to keep her warm. The combination of

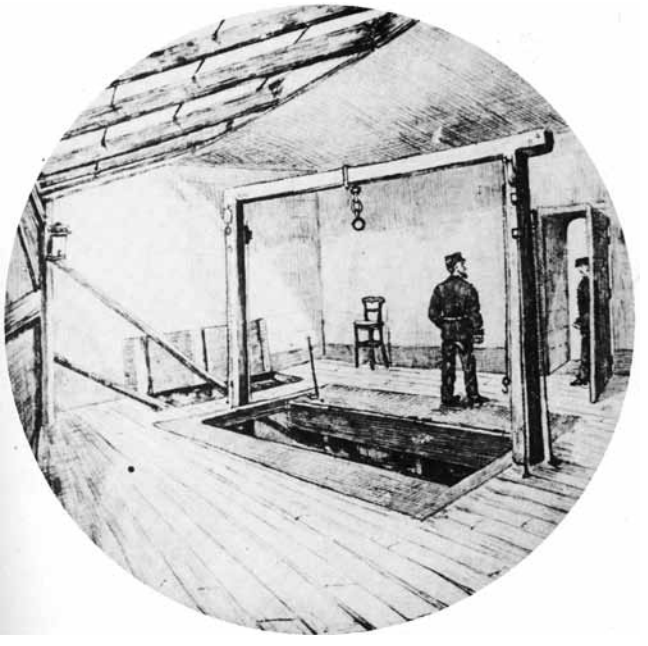

Fig. 5. A Victorian execution shed showing a door trap that is opened by a lever. The beam was set over a 2-leaf trap (12 feet long × 4 feet wide) set level with the surrounding floor. A small trapdoor seen on the left of the drawing allowed easy access to the pit below to examine and remove the body. (Reproduced from Bailey BJ: **Hangmen of England: A History of Execution from Jack Ketch to Albert Pierrepoint.** London: W. H. Allen, 1989.)

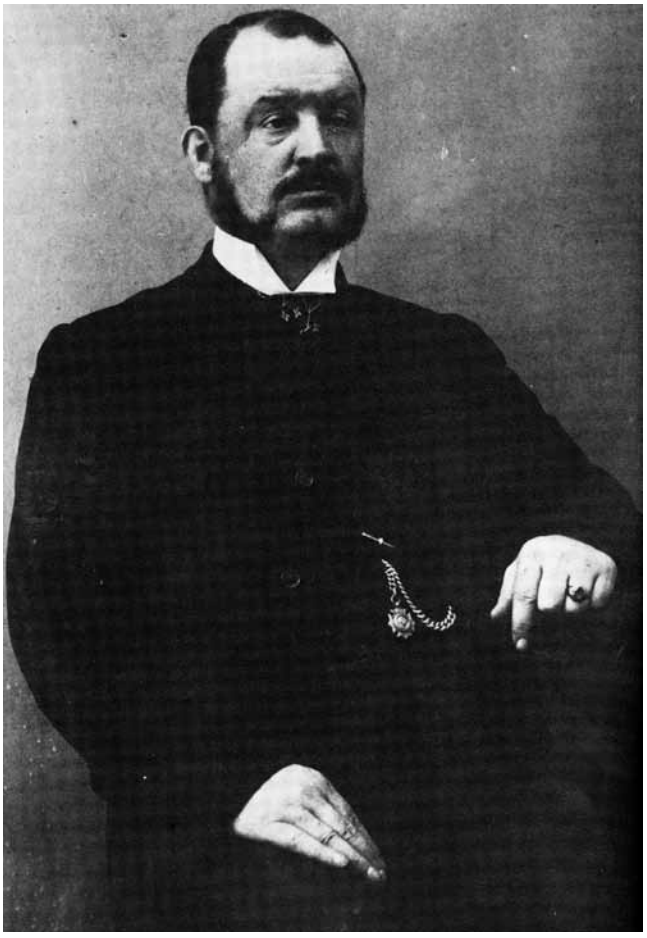

Fig. 6. Portrait of James Berry (1852–1913). Berry carried out 131 hangings in his 7 years in office, from 1884 until 1891. (Reproduced from Bailey BJ: **Hangmen of England: A History of Execution from Jack Ketch to Albert Pierrepoint.** London: W. H. Allen, 1989.)

these efforts brought on her recovery: she started speaking within 12 hours, answered questions within a day, and ate solid food within 4 days. One month later, she had fully recovered, but remained amnesic to the hanging and subsequent revival. She was retried, found innocent, and fully pardoned. Greene went on to marry and had 3 more children.[17]

Mechanisms of Death by Hanging

Hanging can cause death by one or more of the following mechanisms: asphyxia, apoplexy, and fracture of the cervical vertebral column.[5,11] Until the late 1800s, the most likely cause of death from hanging was believed to be asphyxiation. This would explain leaving the prisoner hanging for a prolonged duration after the execution.[5,10] Furthermore, both the belief that death was almost instantaneous and the description of convulsive and jerking movements of the hanged person support the notion that asphyxia was the likely mechanism involved.[5,10,11] However, asphyxiation may not have been the sole cause of death. In 1908, Dr. Frederic Wood-Jones undertook an extensive study of exhumed bodies of 100 Nubian men who were hanged by the Roman Empire at the current site of the Aswan dam along the Nile river. Examination revealed fractures of the skull base that were the most likely cause of death (Fig. 8).[2,5,12,26]

Fracture of the cervical spine was not established as a main mechanism of instantaneous death until Wood-Jones[26] published his seminal work in 1913. However, several reports had previously suggested fracture of the cervical spine as the cause of death, and some even implicated a role for the odontoid process.[3,11,18,23,24] Wood-Jones[26] meticulously examined a series of 5 cervical spine cadavers from the Rangoon Central Jail collected by Captain C. F. Fraser, and he concluded that the odontoid process had no part in causing death. Instead, he noted that the common finding was a fracture of the posterior arch of the axis, which remained attached to the cervical spine below, whereas the anterior part of the axis and the atlas remained attached to the skull base (Fig. 9). This fracture was caused by a violent jerk, which threw the prisoner's head backward and fractured the axis, causing injury to the spinal cord resulting in instantaneous death. All 5 convicts in this series were hanged using a submental knot and a long drop. Having no acquaintance with Wood-Jones' work, Vermooten[24] reported similar cervical spine fractures in 4 "well built coloured men" in 1921. He emphasized that the ligamentum apicis dentis and the ligamentum transversum atlantis remained intact. This type of cervical fracture had not been reported to occur when a subaural knot was used. In 1928, Wolff[25] described cervical fractures in 5 convicts following hanging with a subaural knot. However, Schneider et al.[23] have argued that the subaural knot may have changed into a submental knot during the drop in the cases examined by Wolff.

Submental Versus Subaural Knot

An important factor in the delivery of instant death by hanging was the location of the knot.[5,23,24,26] The tendency in the 1800s was to use a submental knot, which resulted in death by asphyxiation.[26] With the introduction of the long drop, the submental knot was found to be unsuitable, and a subaural knot was substituted. However, the results with the subaural knot were not impressive, and the probable cause of death was still asphyxiation rather than fracture of the cervical spine.[5,26] Subaural knots could cause fracture of the skull base; however, this was less ideal than fracture of the cervical spine.[23,26]

When Wood-Jones[26] made his examinations, he was able to determine the knot position by the location of the skull base fracture. In the same report, he examined the skull of an executed British convict, donated by Dr. G. H. Edington. Wood-Jones found a similar fracture to that of the Nubian skulls, with the knot being on the right side subaurally in this case, and this observation was confirmed by a medical professional who had witnessed the actual hanging. As outlined above, only one report has stated that subaural knots have resulted in cervical spine fractures.[25]

Even before Wood-Jones published his observations, there were several reports favoring the submental knot.[3,4] In 1886, the Committee on Capital Sentences, led by Lord

Fig. 7. Drawing depicting Anne Greene's execution and miraculous resuscitation.

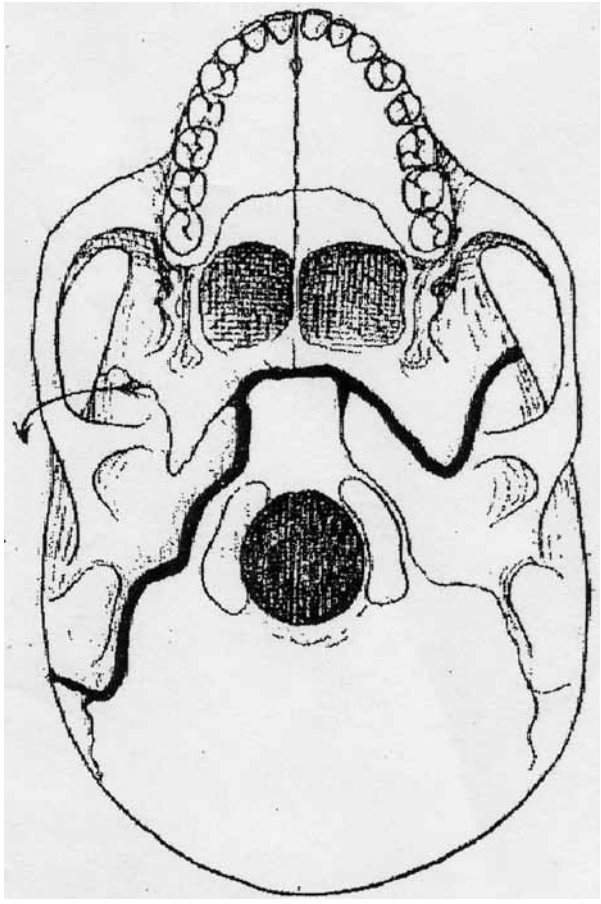

Fig. 8. Drawing showing fracture of the base of the skull. (Reproduced from de Zouche Marshall J: Judicial hanging. **Lancet 1:**639–640, 1913.)

Aberdare, was formed to look into hanging and its shortcomings (Fig. 10). By 1888, the committee was strongly advocating the use of submental knots; however, the group did not make any formal recommendations.[22] After witnessing several hangings in 1886, de Zouche Marshall was convinced that the submental knot was more effective than the subaural knot. Two years later, he developed a padded leather chin trough that helped to maintain the rope in the submental position (Fig. 11).[3,23] However, despite asking for and agreeing with de Zouche Marshall's[4] opinions, the Committee did not formulate any recommendations about using the device. Together with de Zouche Marshall, Wood-Jones,[26] having convincingly demonstrated that cervical spine fractures were caused by submental knots, also strongly advocated substituting the subaural knot with a submental knot for effective and painless execution. In a

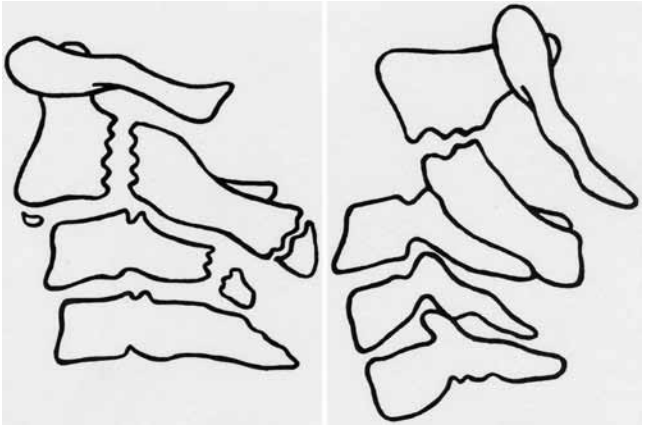

Fig. 9. Drawing showing fracture of the posterior arch of the axis, which remained attached to the cervical spine below, whereas the anterior part of the axis and the atlas remained attached to the skull base.

Fig. 10. Photograph of the Committee on Capital Punishment, chaired by Lord Aberdare.

letter to de Zouche Marshall,[4] Wood-Jones indicated his astonishment that subaural knots were still in use and not being replaced with submental knots.

The Long Drop

The drop was first introduced in 1818, with an initial drop length of 12–18 in.[11,26] Death occurred more rapidly, but was still caused by asphyxiation. Sir Bernard Spilsbury (1877–1947), a pathologist, suggested the addition of at least 3 in to the drop, based on his knowledge gained from postmortem examination of executed convicts.[5] The most important addition to the technique of hanging was the introduction of the long drop to England by Hangman William Marwood in 1872 (Fig. 12).[5,22,23] Interestingly, Marwood was an accomplished boot and shoemaker but developed an interest in capital punishment. He recommended a drop of 7–10 feet.[5] Of note, the concept of long drop was pioneered in Ireland almost 10 years before its introduction in England.[5,11,23] The reluctance to incorporate the long drop in hangings was related to an underlying fear of slippage of the submental knots. Hangmen therefore preferred using subaural knots with the drop.[26] Moreover, cases of decapitation were seen with the use of the long drop. This occurred because of significant variability in the length of the drop, which was left to the hangman's discretion.[4,5,11,26] Of historical interest, the first two cases in which the long drop was used in Ireland resulted in near-complete decapitation in the first case and complete decapitation in the second.[23]

Fig. 12. Portrait of Hangman William Marwood (1820–1883). In his 9 years as a hangman, Marwood hanged 176 convicts. (Reproduced from Bleackley H: **The Hangmen of England: How They Hanged and Whom They Hanged: The Life Story of "Jack Ketch" Through Two Centuries.** Wakefield: EP Publishing [facsimile reprint of 1st ed.], 1976.)

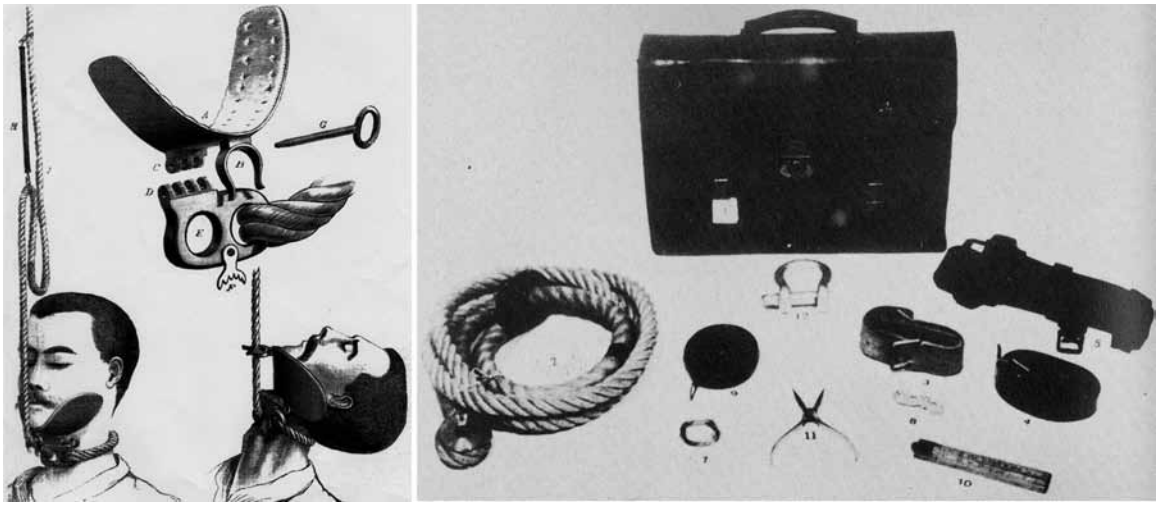

Fig. 11. Drawing of de Zouche Marshall's padded leather chin trough, which was designed to keep the rope ideally in the submental position **(left)**. Photograph of the typical tools of the hangman **(right)**.

TABLE 1: Hangman Berry's table for calculating the length of drop in proportion to weight*

Weight in Stones	Length of Drop
14.0	8 ft 0 in
13.5	8 ft 2 in
13.0	8 ft 4 in
12.5	8 ft 6 in
12.0	8 ft 8 in
11.5	8 ft 10 in
11.0	9 ft 0 in
10.5	9 ft 2 in
10.0	9 ft 4 in
9.5	9 ft 6 in
9.0	9 ft 8 in
8.5	9 ft 10 in
8.0	10 ft 0 in

* Adapted from Duff C: **A New Handbook on Hanging.** London: Andrew Melrose Ltd., 1954.

In addition to standardization of the length of the long drop, Samuel Haughton[11] (1821–1897) estimated that the force needed to kill the convict instantly was 2240 ft-lbs. He also specified the medulla oblongata as the place where this force was to be applied. Haughton used the following formula, known as the "Standard Drop" method: length of drop in feet = 2240/weight of the body in pounds.

Haughton noted that when this force was applied, the condemned was taller by 1.5 in following the hanging. However, he did not explain the reason for this change. Later, James Berry created a similar equation, which allowed for the calculation of the required length of drop (Table 1). Berry used the following formula for his calculations: length of drop in feet = 412/weight of the body in stones.

Berry further modified his calculations after failing to provide an instant and clean execution for Robert Goodale at Norwich Castle on November 30, 1885. He introduced 24 cwt as the required force to kill the convict instantly. Using his new calculations, Berry updated the table accordingly (Table 2). Also known as a hundredweight, cwt is a British imperial unit of weight measurement (1 cwt = 112 pounds = 8 stone). Therefore, 1 stone is equal to 14 lbs.

Later, Henry Bruce led a committee to improve the process of hanging after several failed attempts and decapitations. Their report, published in 1892 and modified in 1913, recommended a new length of drop (Table 3). It was recommended that a force of 1260 ft-lbs be applied at the neck, which was later reduced to 1000 ft-lbs.[4] However, de Zouche Marshall was able to fracture the neck of a cadaver by applying a mere force of 292 ft-lbs. Even today, despite further refinements in technique and revised drop lengths, failures with hanging are still reported. Most recently, the hanging of Barzan Ibrahim al-Tikriti (Saddam Hussein's half-brother) in Iraq on January 15, 2007, was a debacle because it resulted in decapitation.

Biomechanics of Hangman's Fracture

In the 1950s and 1960s, several authors had observed cervical spine fractures following motor vehicle accidents.[2,8,9,23,27] There were even reported cases of decapitation caused by loose safety belts.[27] In 1965, Schneider and colleagues[23] first presented several cases of cervical fractures following car accidents. A note was made by the anatomist, Gilbert Hamilton, about the similarities between the cervical fractures seen following traffic accidents and those occurring following judicial hangings as reported by Wood-Jones. Schneider coined the term "hangman's fracture" in 1965. One can ponder whether the term should be more accurately called "hangee's fracture."

The biomechanics behind this type of fracture were extensively studied by Schneider and colleagues.[23] They noted that the third cervical vertebra forms a fixed point between the craniocervical junction and the lower cervical spine.[23,27] Forces acting downward from the skull through the atlantooccipital and atlantoaxial joints divide in the frontal plane and are united in the axis body. They continue downward, turning 90°, and are distributed in 3 distinct lines, along the line of the vertebral bodies and

TABLE 2: Hangman James Berry's modified table for drop length*

Length of Drop	8 Stones	9 Stones	10 Stones	11 Stones	12 Stones	13 Stones	14 Stones	15 Stones	16 Stones	17 Stones	18 Stones	19 Stones
1 ft	8	9	10	11	12	13	14	15	16	17	18	19
2 ft	11	12	14	15	16	18	19	21	22	24	25	26
3 ft	13	15	17	19	20	22	24	26	27	29	31	33
4 ft	16	18	20	22	24	26	28	30	32	34	36	40
5 ft	17	19	22	24	26	28	30	33	35	37	39	41
6 ft	19	22	24	26	29	31	34	36	39	41	44	46
7 ft	21	23	26	29	31	34	37	39	41	45	47	50
8 ft	22	25	28	31	34	36	39	42	45	48	51	53
9 ft	24	27	30	33	36	39	42	45	48	51	54	57
10 ft	25	28	31	34	37	41	44	47	50	53	56	60

* Rule: take the weight of the convict in stones (1 stone = 14 lbs) and look down the column of weights until you reach the values nearest to 24 cwt (in gray shading); the figure in the left-hand column will be the drop length (adapted from Duff).

TABLE 3: Comparison of length of drop between the 18th century and the current time*

Body Weight	Berry's Drop		Modern Drop
	Original	Modified	
14.0 stones (196 lbs)	8 ft 0 in	3 ft 0 in	5 ft 5 in
13.5 stones (189 lbs)	8 ft 2 in		5 ft 6 in
13.0 stones (182 lbs)	8 ft 4 in	3 ft 6 in	5 ft 8 in
12.5 stones (175 lbs)	8 ft 6 in		5 ft 11 in
12.0 stones (168 lbs)	8 ft 8 in	4 ft 0 in	6 ft 1 in
11.5 stones (161 lbs)	8 ft 10 in		6 ft 1 in
11.0 stones (154 lbs)	9 ft 0 in	5 ft 0 in	6 ft 6 in
10.5 stones (147 lbs)	9 ft 2 in		6 ft 8 in
10.0 stones (140 lbs)	9 ft 4 in	6 ft 0 in	7 ft 1 in
9.5 stones (133 lbs)	9 ft 6 in		7 ft 5 in
9.0 stones (126 lbs)	9 ft 8 in	7 ft 6 in	7 ft 7 in
8.5 stones (119 lbs)	9 ft 10 in		7 ft 9 in
8.0 stones (112 lbs)	10 ft 0 in	9 ft 0 in	8 ft 0 in

* Adapted from Duff.

discs medially, and along the line of the pre- and postzygapophyses bilaterally. These 3 lines pass through the weakest part of the neural arch of the axis, which is prone to fracture, causing an avulsion fracture of the axis.[23]

During judicial hanging with a submental knot, a hyperextension-distraction effect is produced by the knot and the drop. This results in rupture of the ligament system, fixing the cervical spine ventrally, and leaning of the arch of the axis on the third cervical vertebra and, as a consequence, its fracture. The continuous longitudinal traction results in complete detachment of the cervical spine from the cervicocranial junction, and results in extremely serious neurological consequences that are usually fatal.[27] On the other hand, the cervical injuries seen in car accidents result from a hyperextension-compression mechanism of injury.

In the 1981, 3 independent authors introduced classification schemes to identify various types of traumatic spondylolisthesis of the axis and to guide treatment paradigms.[6,7,19] These classifications were primarily based on the appearance and putative mechanisms of the injury. Pepin and Hawkins[19] proposed a 2-type classification for hangman's fractures. Type I was defined as nondisplaced fracture of the posterior elements. In Type II fracture, there was displacement of the posterior elements and C-2 body. This concept was incorporated in the classification system reported by Francis et al.,[7] based on their collective experience with 123 patients. The investigators separated the injuries into 5 types based on the amount of displacement and the degree of angulation of the axis on C-3. However, it was Effendi and coworkers[6] who, also in 1981, published their classification system based primarily on the mechanism of injury. In 1985, Levine and Edwards[14] modified Effendi's classification scheme. Two further modifications were put forward by Levine in 1991 and 1998, as outlined in Table 4.[13,15] The scheme proposed

TABLE 4: Modern classification schemes of hangman's fracture

Authors & Year	Basis of Classification	Type	Description
Effendi et al., 1981	radiographic evaluation & clinical course	I	isolated hairline fractures of the pedicle of axis, w/ minimal displacement of C-2 body
		II	displacement of anterior fragment, w/ disc disruption below the axis (flexion, extension, spondylolisthesis)
		III	fixed displacement & angulation of anterior segment, w/ dislocated & locked facet joints at C2–3
Levine & Edwards, 1985	mechanism of injury	I	axial loading & hyperextension
		II	hyperextension-axial loading force associated w/ severe flexion
		IIa	flexion-distraction, mild or no displacement, but very severe angulation
		III	flexion-compression
Levine & Rhyne, 1991	modification of earlier system	III subtypes	bipedicular fractures w/ bilat facet dislocation, unilat facet injury or dislocation bound to contralat neural arch fracture; bilat facet dislocation combined w/ bilaminar fractures of C-2
Levine, 1998	modification of earlier system	Ia	minimal translation & little or no angulation, elongation of C-2 body

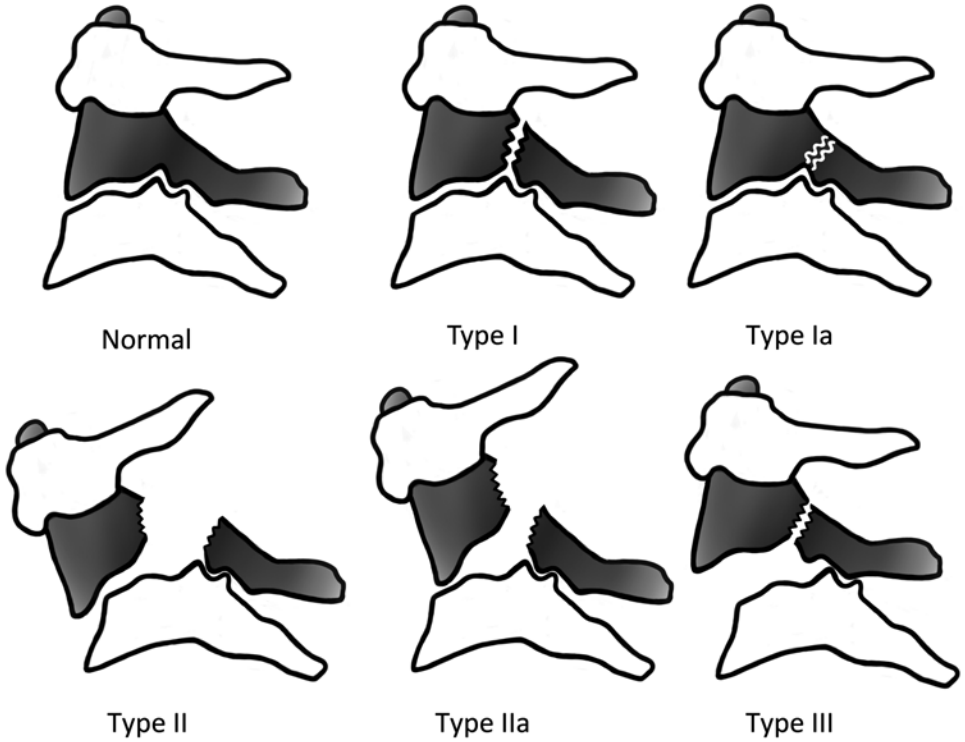

Fig. 13. Classification system of Levine and Edwards.

by Effendi et al. and later modified by Levine and Edwards is the most widely used and most practical classification system (Fig. 13). It provides clinically reasonable guidelines for effective management of hangman's fractures based on morphological features and stability of the fracture.[16,20]

Concluding Remarks

In 1846, the State of Michigan became the first English-speaking government in the world to abolish capital punishment (for all crimes except treason). Judicial hanging was abolished in England in 1965. The last execution by hanging in American history was in 1996 in Delaware. Currently, only a handful of countries around the world still use hanging as capital punishment. In the US, only the states of New Hampshire and Washington presently allow hanging as an option. Therefore, hangman's fractures are encountered mainly following motor vehicle or diving accidents. Nevertheless, hanging as a method of carrying out a death sentence, when performed correctly, is arguably one of the most humane ways of execution.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: S Mittal, Rengachary. Acquisition of data: S Mittal, Rayes, M Mittal. Analysis and interpretation of data: S Mittal, Rayes, M Mittal. Drafting the article: Mittal, Rayes, Mittal. Critically revising the article: S Mittal, M Mittal. Reviewed final version of the manuscript and approved it for submission: all authors. Administrative/technical/material support: S Mittal. Study supervision: S Mittal.

Acknowledgments

This paper was one of Dr. Rengachary's last clinical endeavors. The authors fondly remember his kindness and fervent scientific acumen. The authors also thank Mr. Brandon Parker for editorial assistance and Mr. Jon Thompson for help with figures.

References

1. Colice GL: Historical background, in Tobin MJ (ed): **Principles and Practice of Mechanical Ventilation.** New York: McGraw-Hill, 1994, pp 1–35
2. Cornish BL: Traumatic spondylolisthesis of the axis. **J Bone Joint Surg Br 50:**31–43, 1968
3. de Zouche Marshall JJ: Judicial executions. **BMJ 2:**779–786, 1888
4. de Zouche Marshall JJ: Judicial hanging. **Lancet 1:**194, 1913 (Letter)
5. Duff C: **A New Handbook on Hanging.** London: Andrew Melrose Ltd., 1954
6. Effendi B, Roy D, Cornish B, Dussault RG, Laurin CA: Fractures of the ring of the axis. A classification based on the analysis of 131 cases. **J Bone Joint Surg Br 63-B:**319–327, 1981
7. Francis WR, Fielding JW, Hawkins RJ, Pepin J, Hensinger R: Traumatic spondylolisthesis of the axis. **J Bone Joint Surg Br 63-B:**313–318, 1981
8. Garber JN: Abnormalities of the atlas and axis vertebrae—congenital and traumatic. **J Bone Joint Surg Am 46:**1782–1791, 1964
9. Grogono BJS: Injuries of the atlas and axis. **J Bone Joint Surg Br 36:**397–410, 1954
10. Hammond GM: On the proper method of executing the sentence of death by hanging. **Med Rec 22:**426–428, 1882
11. Haughton S: On hanging, considered from a mechanical and

physiological point of view. **London Edinburgh Dublin Philosophical Magazine and Journal of Science 32:**23–34, 1866
12. Jones FW: The examination of the bodies of 100 men executed in Nubia in Roman times. **BMJ 1:**736–737, 1908
13. Levine AM: Traumatic spondylolisthesis of the axis (Hangman's fracture), in Levine AM, Eismont FJ, Garfin SR, et al (eds): **Spine Trauma.** Philadelphia: WB Saunders, 1998, pp 278–299
14. Levine AM, Edwards CC: The management of traumatic spondylolisthesis of the axis. **J Bone Joint Surg Am 67:**217–226, 1985
15. Levine AM, Rhyne AL: Traumatic spondylolisthesis of the axis. **Semin Spine Surg 3:**47–60, 1991
16. Li XF, Dai LY, Lu H, Chen XD: A systematic review of the management of hangman's fractures. **Eur Spine J 15:**257–269, 2006
17. Molnár Z: Thomas Willis (1621-1675), the founder of clinical neuroscience. **Nat Rev Neurosci 5:**329–335, 2004
18. Paterson AM: Fracture of the cervical vertebrae. **J Anat Phys 24:**ix, 1890
19. Pepin JW, Hawkins RJ: Traumatic spondylolisthesis of the axis: Hangman's fracture. **Clin Orthop Relat Res (157):**133–138, 1981
20. Pryputniewicz DM, Hadley MN: Axis fractures. **Neurosurgery 66 (3 Suppl):**68–82, 2010
21. Rengachary SS, Xavier A, Manjila S, Smerdon U, Parker B, Hadwan S, et al: The legendary contributions of Thomas Willis (1621–1675): the arterial circle and beyond. Historical vignette. **J Neurosurg 109:**765–775, 2008
22. Robertson WGA: Recovery after judicial hanging. **BMJ 1:** 121–122, 1935
23. Schneider RC, Livingston KE, Cave AJ, Hamilton G: "Hangman's fracture" of the cervical spine. **J Neurosurg 22:**141–154, 1965
24. Vermooten V: A study of the fracture of the epistropheus due to hanging with a note on the possible causes of death. **Anat Rec 20:**305–311, 1921
25. Wolff R: Injury to the cervical vertebrae as a result of judicial hanging. **Journal of Medical Association of South Africa 2:**460–462, 1928
26. Wood-Jones F: The ideal lesion produced by judicial hanging. **Lancet 1:**53, 1913
27. Zsolczai S, Pentelényi T: The modern approach of hangman's fracture. **Acta Chir Hung 31:**3–24, 1990

Manuscript submitted October 5, 2009.
Accepted October 7, 2010.
Please include this information when citing this paper: published online December 24, 2010; DOI: 10.3171/2010.10.SPINE09805.

Address correspondence to: Sandeep Mittal, M.D., F.R.C.S.C., Department of Neurosurgery, Wayne State University, 4160 John R Street, Suite 930, Detroit, Michigan 48201. email: smittal@med.wayne.edu.