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CASE REPORT

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Investigation of Italy's Deadliest Building Collapse: Forensic Aspects of a Mass Disaster*

ABSTRACT: We describe the investigation of the 1999 collapse of an apartment building in Foggia, Italy. Sixty-one victims were recovered in the rubble of the building, and five people were unaccounted for. All the bodies were well preserved except for two who had been burned. The majority of the victims were identified visually or by comparing body features, clothing, or personal effects with information collected from relatives or friends. Positive identifications of the two victims who were burned were obtained by dental comparison and DNA analysis. Approximately half of the victims (51.6%) sustained fatal injuires, while the remainder died from asphyxia. The injuries were characterized using the Abbreviated Injury Scale (AIS) and the New Injury Severity Score (NISS) systems. Injury severity associated with the location of victims inside the apartment may provide useful information for those involved in building design and/or search and rescue operations. Engineers determined that the collapse was the result of the use of inappropriate foundation material.

KEYWORDS: forensic science, mass disaster, building collapse, trauma fatalities, anatomical scoring systems, abbreviated injury scale (AIS), new injury severity score (NISS)

In the early morning of November 11, 1999, a six-story apartment building collapsed in Foggia, Italy, killing many of the residents who were sleeping and others who were trying to escape (Fig. 1). The building was approximately 30 years old. Minutes before the collapse, some tenants heard a loud cracking sound coming from the cement pillars. The building collapsed, floor upon floor, starting from the center where the stairways were located (Fig. 2). Several days before, residents had complained to local officials that they feared the building was unsafe. The collapse reduced the building to rubble approximately one story high, and a gas fire was ignited in part of the ruins.

Fire department and military rescue personnel immediately began search-and-rescue operations. Of the 76 people in the building, ten were found alive within 36 h of the collapse. One man died 12 h after being rescued. Sixty-one bodies were recovered from the building and five people were not accounted for.

Soon after the disaster, the state attorney engaged two groups of experts: engineers and forensic pathologists. The engineers were tasked with determining the cause of the accident and the pathologists with identifying the victims and determining the cause and manner of death. The latter team consisted of five forensic pathologists, all of whom were familiar with anthropological procedures employed for personal identification.

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Postmortem Examinations

Postmortem examinations were performed at a site a few miles from the accident. The site was divided into three sections (1): the first for receiving the bodies and for victim identification; the second for retrieval of personal effects, photographing the remains and postmortem examination; and the third for retention of the bodies until their release.

Over four days 62 bodies (Table 1) were examined. All the victims were well preserved except two who had been burned by the gas explosion. The majority of the victims wore night clothes or were only partly dressed. Only eight of the bodies were fully dressed and were found in the stairways, suggesting that they were unable to escape. A number of witnesses observed people trying to escape from the collapsing building.

The majority of bodies were identified visually and/or by comparing body features (i.e., scars, dental or orthopedic prostheses, previous surgery, etc.) and/or clothing or personal effects with information previously collected from relatives or friends. One of the two burned bodies was identified by dental records and the other by DNA analysis.

Autopsies were performed on 34 bodies. The external and autopsy findings showed that 31 of the victims died quickly due to the severity of their injuries. Twenty-nine people (48.3%) died of mechanical asphyxia, defined according to Di Maio and Dana (2), as "pressure on the chest and abdomen that restricts respiratory excursion, upper airway obstruction or entrapment suffocation." For eleven of the victims, asphyxial death was associated with moderate trauma such as craniofacial injuries, multiple rib fractures, musculoskeletal fractures, laceration and/or contusion of internal organs. In 14 victims there was no evidence of significant trauma in spite of the compressive forces involved. The face and neck were

FIG. 1—*Aerial view of the six-story apartment building before and after the collapse.*

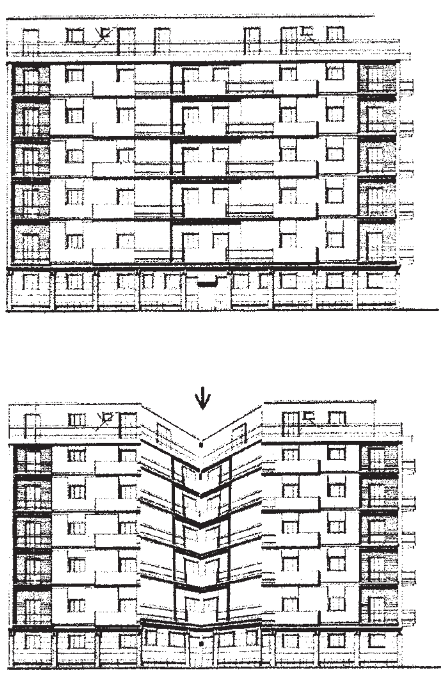

FIG. 2—*The pancaking collapse as the building fell on itself floor upon floor starting from the center, where the stairways were located.*

TABLE 1—*Age and sex distribution of the cases.*

Age, years	M	F	Total
00–10	3	1	4
11–20	3	8	11
21–30	7	5	12
31–40	3	4	7
41–50	6	4	10
51–60	4	4	8
61–70	4	2	6
>70	2	2	4
Total	32	30	62

TABLE 2—*Causes of death of the 62 victims.*

Bodies Recovered	Cause of Death
31	Multiple injuries
11	Moderate injuries and traumatic asphyxia
14	Traumatic asphyxia alone
4	Environmental suffocation
2	Undetermined due the poor condition of the bodies
Total 62	

cyanotic secondary to congestion, associated with numerous petechiae of the conjunctivae and sclerae. Contusions or abrasions of the chest and abdomen were consistent with external pressure preventing respiration (mechanical asphyxia).

In four victims, nonspecific acute visceral congestion was observed. In these bodies there were no significant injuries except for minor contusions and abrasions. The cause of death was determined to be hypoxia due to suffocation resulting from being trapped in a location where there was insufficient oxygen. The cause of death in two victims was undetermined due to the extent of thermal injury. Carboxyhemoglobin levels (<20%) were inconsistent with the inhalation of combustion products. It could not be determined whether they died before or after the fire. Table 2 breaks down the cause of death for all the victims.

Injury Distribution

Significant trauma was observed in most of the bodies with multiple regions of the body often involved. For all victims, the injuries were classified by body area (head or neck, chest, abdomen and back, extremities, external). The two charred bodies were excluded from this analysis. The distribution of injuries among the 60 cases investigated is shown in Table 3.

Twenty-four people had fractures of the skull and facial bones; in twelve, these were complicated by subdural hematomas and/or brain contusions. Nine were found to have fractures at the base of the skull.

In 47 cases the thorax was the most frequently injured region. Twenty-two of those with a head injury also suffered chest injuries.

TABLE 3—*Regional distribution of injuries among the 60 victims.*

Injury	Number
Head and Neck	26
Skull and spine fracture	24
Brain contusion/laceration	12
Chest	47
Chest wall injury	47
Heart and lung contusion/laceration	19
Abdomen and Back	15
Intraabdominal organ rupture	13
Spine fracture	11
Extremities	36
Arms	30
Legs	32
External	58
Superficial wounds	58
Lacerations	45
Burns	4

TABLE 4—*Degree of severity of injuries according to the AIS six grades.*

AIS Score	Victims
0	1
1	2
2	3
3	10
4	11
5	15
6	18
	Total 60

TABLE 5—*The New Injury Severity Score (NISS) in 60 bodies.*

NISS	Number	I	I+TA	TA	ES
0–09	6	. . .	. . .	2	4
10–29	13	. . .	1	12	. . .
30–50	9	. . .	9	. . .	. . .
51–66	14	13	1	. . .	. . .
67–75	18	18	. . .	. . .	. . .
Total	60	31	11	14	4

Legend: I = multiple injuries.
I+TA = moderate injuries and traumatic asphyxia.
TA = traumatic asphyxia alone.
ES = environmental suffocation.

The primary cause of thoracic injury was blunt trauma. Most of the chest injuries consisted of multiple rib fractures, associated with cyanosis of the face, congestion, and conjunctival petechiae. In 19 cases, heart and lung contusions and/or lacerations were observed.

Thirteen victims had abdominal injuries, with laceration of internal organs, liver, spleen, or kidney. Eleven sustained fractures of the thoracic or lumbar spine.

Fractures of the upper and lower extremities were found in 36 cases. The survivor who died after being rescued suffered amputation of the upper right limb and multiple rib fractures. Four cases had superficial burns located on exposed parts of the body, especially the face, arms and legs.

Material and Methods

A more objective evaluation of the severity of the injuries found was performed using the Abbreviated Injury Scale (AIS) and the New Injury Severity Score (NISS) systems. The AIS and its derivative Injury Severity Score (ISS) are the most widely used anatomical trauma scoring systems (3,4). The applicability of these scoring methods to autopsy findings has demonstrated their usefulness in accident reconstruction and injury prevention (5).

Injuries were classified according to the six AIS grades (1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, 6 = unsurvivable) and the codes available in the AIS-90 manual (6). The two burned bodies and the hospitalized survivors were excluded from this evaluation. Table 4 shows the injuries observed in each body; however, since most of the 60 bodies had multiple injuries, the NISS was used to evaluate the total injury pattern.

As a summary of anatomic injury, the NISS was performed according to the procedure described by Osler et al. (7). The NISS is defined as the sum of the squares of the AIS scores of each of the three most severe AIS injuries regardless of the body region in which they occur. All bodies were included in the evaluation, even cases of asphyxia where the mechanism of death does not produce major anatomic changes that may be coded by the AIS. Based on the different causes of death observed among the victims, we have identified five groups of NISS; the distributions are shown in Table 5.

Results

The 60 victims were divided into five NISS groupings (Table 5). The first group (NISS 0 to 9) includes scores reflecting no or superficial injuries found in six victims. Entrapment suffocation was the cause of death in four victims and mechanical asphyxia (compression of the chest) in two.

The second group (NISS 10 to 29) includes scores reflecting minor injuries such as large skin contusions, lacerations, musculoskeletal fractures and/or rib fractures with signs of trunk compression (cyanosis of the face, congestion and conjunctival petechiae) observed in 13 victims. Most of these died by mechanical asphyxia. Only one case had a brain contusion considered sufficient enough to have contributed to death.

The third group (NISS 30 to 50) includes a range of moderate injuries present in nine victims. The predominant cause of death was the association of traumatic asphyxia with injuries mostly distributed on the chest wall and abdomen with multiple rib fractures, laceration and/or contusion of internal organs, craniofacial injuries, musculoskeletal fractures, etc.

The fourth group (NISS 51 to 66) includes scores reflecting serious and/or critical injuries observed in 14 victims in whom trauma was considered the primary cause of death. In all but one case, injuries to the head and chest were not sufficient to have caused death.

The fifth group (NISS 67 to 75) includes the highest NISS reflecting injuries that by definition are incompatible with life, such as massive lacerations of the thoracic or abdominal walls with deformation and exposure of internal organs, rupture of the heart, liver, lacerations of major vessels, etc. Eighteen bodies were assigned to this highest group. Most of the 31 victims who had multiple fatal injuries were included in the fourth and fifth groups, confirming that trauma was the cause of death in these cases.

Discussion

Application of trauma-scoring systems in autopsies can be of great value in accident reconstruction. Low post-mortem NISS occurs in deaths that probably could have been avoided if the search and rescue team had been able to find these individuals in time. The autopsy findings showed that 31 victims (51.6%) sustained critical injuries or injuries incompatible with life. The other 29 victims (48.3%) suffered only moderate or minor injuries associated with traumatic asphyxia; they died beneath the rubble with external pressure preventing adequate respiration.

A NISS of 9 or less was assigned to six people, four of whom presumably died of suffocation because of the absence of injuries or other causes. A NISS of 10 to 50 was assigned to 22 people, the majority of whom suffered no significant trauma. The primary cause of death among these victims was traumatic asphyxia based on signs of mechanical compression of the chest and congestion, for example cyanosis and conjunctival petechiae. Although it was not possible to determine whether those trapped died immediately or survived for some time under the debris, some of them might have survived if recovery had come sooner.

Collapsed structures can contain spaces where survivors can remain alive for brief periods. To determine where these spaces are, information on the construction of the building and the potential pattern of collapse should be considered by search and rescue teams (8). Unfortunately, this information is rarely available. After the accident the engineering team determined that the cause of the

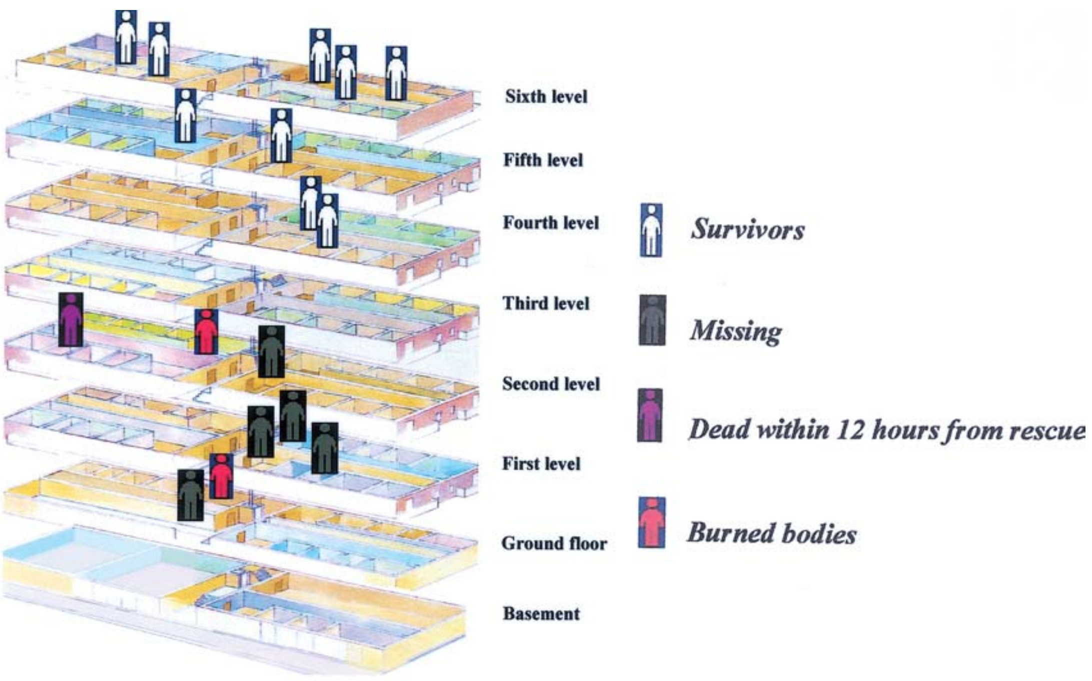

FIG. 3—*Presumptive distribution of the survivors and the missing victims considering the location of their apartments.*

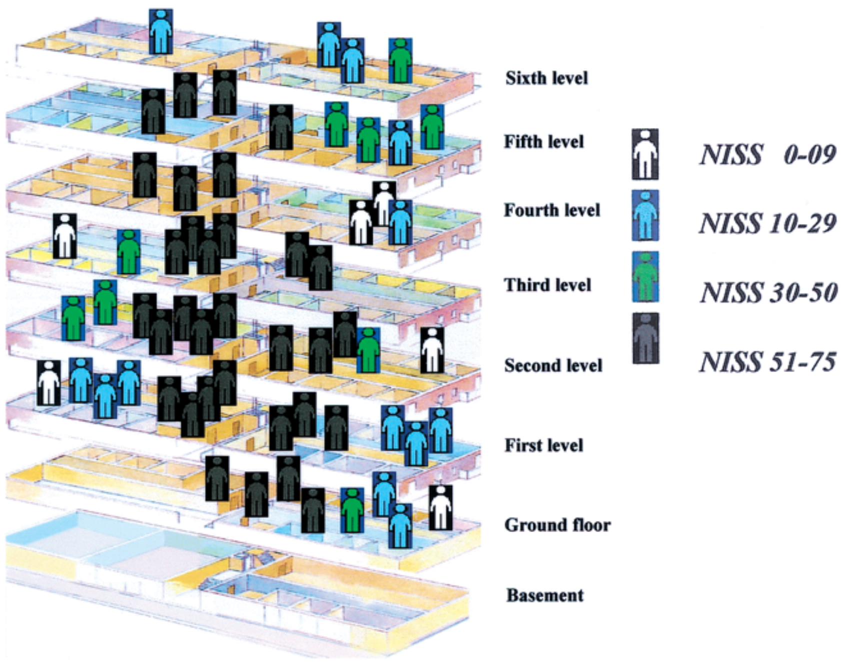

FIG. 4—*Presumptive distribution of the 60 victims considering the location of their apartments and the NISS cohorts.*

collapse was a failure of the building foundations. These were constructed with inappropriate materials.

In such accidents, recovery of remains is difficult and the search and recovery teams are often at risk themselves (9). If information on the potential location of the victims and on the severity of their injuries was available, it would be of great assistance to these teams.

The presumed distribution of victims after the collapse was determined based on their apartments' location. Most survivors were residents of the upper floors. All five missing people lived in apartments located on the lower floors in the central part of the building and very close to the stairways (Fig. 3).

The location of the rest of the victims was also consistent with an increased risk of death for tenants living on the lower floors. This was not true in the Oklahoma City bombing (Alfred P. Murrah Federal Building), where there was an increased risk of death for those working on the upper floors because a bomb explosion external to the building caused the collapse (10). The height of the building and location of the individuals on upper floors were also high-risk factors for injury and death among the victims of the earthquake that struck Northern Armenia in 1988 (11).

In this accident all the victims with NISS of less than 30 lived in peripheral areas of the building, far from the stairways (Fig. 4). Victims located on lower levels and close to the central part of the building, near the stairways, had more severe injuries.

According to Coburn et al. (12), the factors determining the number of people killed after a building collapse can be summarized as follows: level of occupancy, circumstances of entrapment, injury severity, length of time without medical attention, and speed of rescue. Based on our experience, the response time for search and rescue is absolutely critical. Observations made in Italy after the Campania-Irpinia earthquake in 1980 (13,14) and in China after the Tangshan earthquake in 1976 (15) show that the proportion of people found alive decreases with increasing time post-accident. In the Italian study, 93% of those trapped who survived were recovered within the first 24 h. Estimates of survival for entrapped victims buried under collapsed buildings in Turkey indicate that, within 2 to 6 h, less than 50% of those buried are still alive (16).

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