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A Review of Crane Deaths in Jefferson County, Alabama*

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ABSTRACT: Cranes are machines used to move heavy objects. Cranes are operated by crane operators, usually working in conjunction with an assistant guiding the movements of the crane from his vantage point outside the crane. Few jurisdictions require that crane operators be either licensed or certified. We conducted a retrospective study of those dying of crane-related injuries in our jurisdiction during the 16 years from 1981 to 1996. All ten decedents were male, and the manner of each death was accidental. Neither ethanol nor drugs of abuse were detected in any case. Eight of the ten decedents died due to blunt force injuries, one due to mechanical asphyxia, and one due to thermal burns. Investigation by the Occupational Safety and Health Administration (OSHA) led to fines ranging from $80 to $2700 in six of the ten cases. Nationwide, electrocution is the most common cause of crane-related death, but no crane-related death in Jefferson County was caused by electrocution in our study. The absence of electrocutions was due to the planned, routine suspension of power to electrical lines in the vicinity of a crane during the crane's operation, a practice saving an estimated seven lives. Nevertheless, human error or lack of planning was still responsible for most of the deaths in our study. In addition to careful planning and adherence to safety standards established by planning, we recommend the mandatory licensure and certification of professional crane operators and the assessment of larger fines by OSHA for safety standard violations.

KEYWORDS: forensic science, forensic pathology, death, accident, Alabama, crane, industrial accident, blunt force trauma, mechanical asphyxia, electrocution

Cranes are machines used to raise, shift, or lower heavy objects by means of an integral hoist mechanism (1). Cranes have three basic mechanical components that work in combination—a powerful motor attached to a pulley mounted on a mobile lever arm, called the boom. The movements of a crane are controlled by a human operator and his assistant. A recent request to present an overview of industrial accidents prompted us to review our experience with crane deaths and, in the process, to learn more about the operation of cranes.

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Background

Types of Cranes

Many different types of cranes exist, each designed to move objects in a particular environment or on a particular terrain (1,2). In essence, however, a crane is either stationary or mobile (see Figs. 1–3).

Stationary cranes used in construction are called tower cranes and are typically seen at urban construction sites. Two basic types of tower cranes exist. In one type the crane is assembled as an integral part of the building being constructed, rising as the building rises (2). The other type of tower crane is erected adjacent to the building being constructed. When a tower crane is erected adjacent to a building, then the crane itself is a sort of building whose base is joined to a concrete foundation. Some states require an operating permit, indicating that an assembled tower crane has been inspected by a certifier, before the crane can be used (3). Tower cranes are expensive, and they become cost-effective only when a crane will be needed at a site for several weeks or more. Once a tower crane has completed its job it is disassembled and removed.

A separate form of stationary crane, called an overhead crane, is used in a factory such as a steel mill. An overhead crane is mounted on tracks near the ceiling over a work bay. The crane can move back and forth along the tracks, moving objects below from one end of the work bay to the other. The crane is guided along the tracks by the crane operator. In effect, an overhead crane may be thought of as the boom of a tower crane, but with the boom held aloft by the walls of a building, not by a tower component.

Mobile cranes are mobile in some way, and may be further classified according to the means by which they are mobile. Some mobile cranes are mounted on caterpillar treads like those of a bulldozer (Fig. 2). Caterpillar treads provide these crawler cranes with a wide base over which their weight and load are distributed, giving such cranes the advantage of being able to move about the job site while carrying a load. The disadvantage of caterpillar treads is that crawler cranes must be transported from job site to job site on a flatbed truck or railroad flatcar. Some mobile cranes have rubber tires, which allow the cranes to be driven from site to site via public roads as one would drive a truck (Fig. 3). Rubber tires do not provide a wide enough base for the safe operation of such a truck crane, however. Therefore, before a truck crane can be operated it must first be positioned and stabilized. Stabilization of a truck crane requires the deployment of outriggers, retractable supports that are extended from the chassis (see Fig. 3). If the ground is soft or uneven the crane may have to be jacked up on a mat of steel or timber, called "cribbing," over which the weight of the crane is distributed. Truck cranes can have either a telescopic boom, where the boom consists of multiple sleeves extended hydraulically (see Fig.

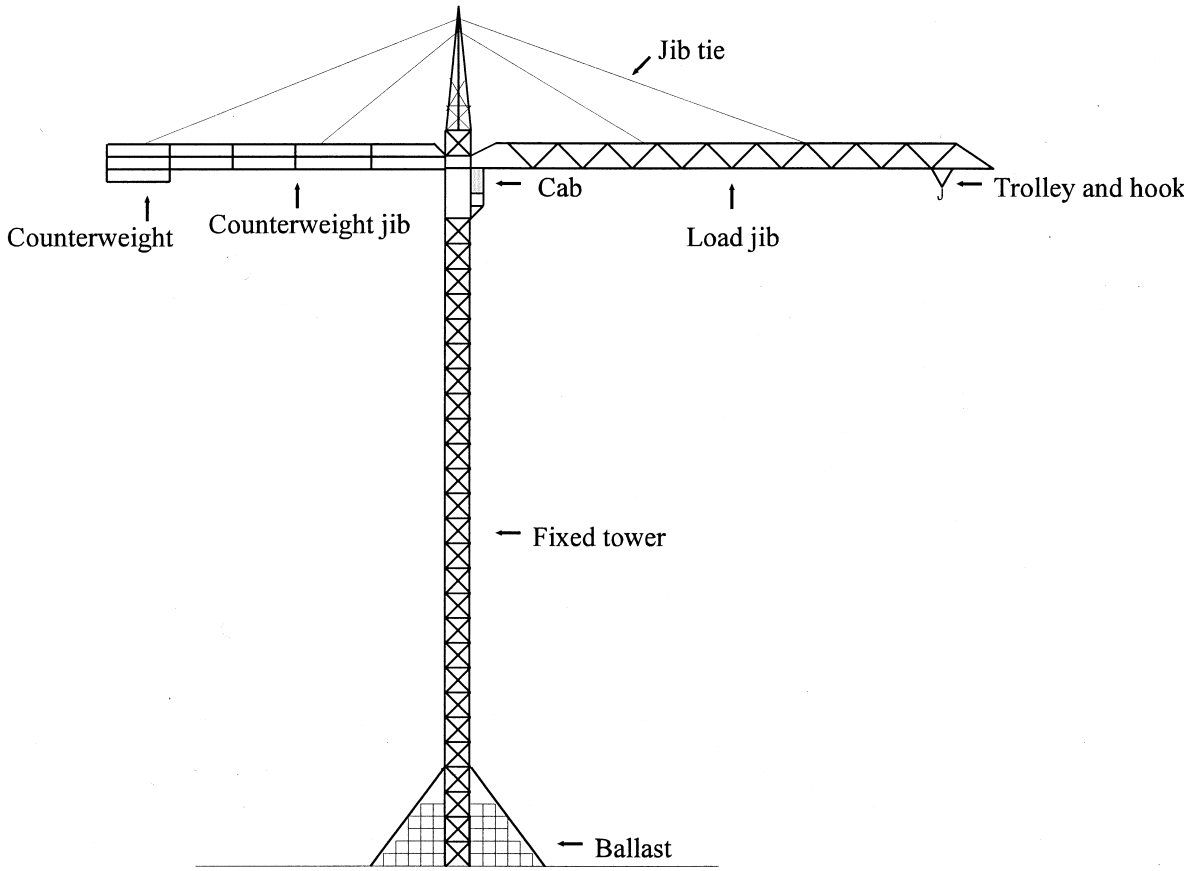

FIG. 1—*Simple illustration of a stationary tower crane.*

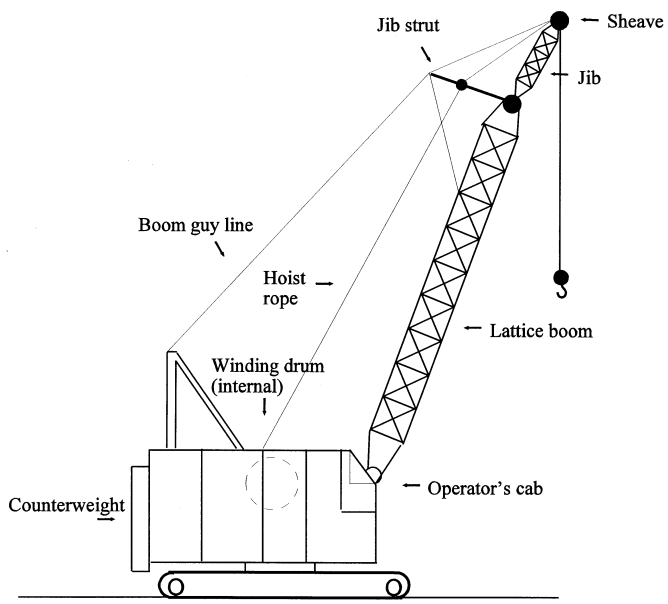

FIG. 2—*Simple illustration of a mobile crawler crane with a lattice boom.*

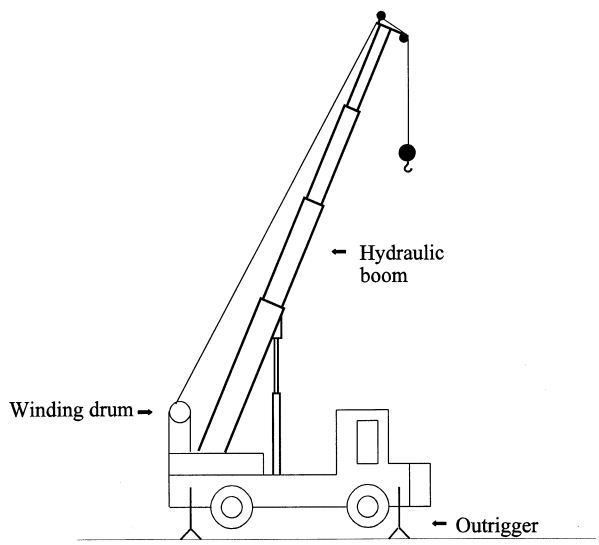

FIG. 3—*Simple illustration of a mobile truck with hydraulic boom, outriggers deployed.*

3), or a more conventional lattice boom (see Fig. 2). A telescopic boom is more expensive to construct initially than a lattice boom, but a telescopic boom has the advantage of speed, for a lattice boom must often be assembled from a few shorter segments at each new job site before work can begin.

Crane Operator

A crane is operated by a crane operator. If the crane operator should be working in an open field, he might be able to work alone. In most cases, however, the motion of the crane is limited to some extent by nearby structures, and so the crane operator works in conjunction with an assistant who helps guide the movements of the

crane and its load from his vantage point outside the crane. This assistant is variously called a flagger (an older term) or a radio man. The operator and his assistant work together as a team, communicating by hand signals and radio. Most crane operators learn their trade over the course of a few years in a union training program. Employers have relied in the past on union or union-trained crane operators as their guarantee of proper credentials and experience, and to a large extent this practice continues today. According to the North American Crane Bureau, only four states (Oregon, New Mexico, New Jersey, and Washington) and three cities (Los Angeles, Chicago, and New York) require that crane operators working within their jurisdiction be licensed. Otherwise, a crane operator needs no license to operate a crane, although they do need a heavy truck license to drive a mobile crane on a public roadway. Recent advances in technology have been applied to cranes, making cranes more complicated to operate (1). In order to assure safety and limit liability, some states, some cities, and more and more companies that hire crane operators are requiring that the operators be certified. Being "licensed" and being "certified" are not synonymous. A license grants its bearer permission to engage in a specific practice, with authority to enforce compliance with certain standards. Certification indicates that certain established requirements or standards have been met by the one certified (1). (In the same way, a medical license is distinct from certification by a medical board.) Perhaps one reason that licensure or certification for crane operators has not been made mandatory earlier is that crane operators tend to be cautious workers. A competent crane operator commands a good salary and has much to lose by taking foolish risks that might damage his machine, professional reputation, and livelihood.

Materials and Methods

We conducted a restrospective study of all individuals brought to the Jefferson County Coroner/Medical Examiner office during the 16 years from 1981 to 1996. Cases in which death was associated with a crane were identified by a computer search for all individuals in which "crane" was listed as the weapon that caused the injury that caused death. (In our database "weapon" is any object that was instrumental in causing death, regardless of whether it was wielded with malicious intent. For example, a stove is considered a weapon if it caused a house fire which caused death.) This yielded four cases. In addition, review of deaths that occurred on job sites revealed an additional six cases where death was related to a crane. The investigative reports and postmortem findings for these ten cases were reviewed, and the data gathered were entered into a computer spreadsheet for analysis. Information concerning the findings of the Occupational Safety and Health Administration (OSHA) on each case was obtained from the Internet at http://www.osha.gov/oshstats.

Results

The ages of the decedents ranged from 22 to 62 years with an average age of 39 years (standard deviation 12 years). All decedents were male. Five decedents were white, and five were black. Five were union employees, and five were non-union. The manner of death was accident in all cases. Toxicological analysis detected neither ethanol nor drugs of abuse in any decedent. Our findings are summarized in Table 1. Following is a brief description of each case.

TABLE 1—*Summary of findings in crane deaths in Jefferson County. Note that all deaths were of workers outside the crane with the exception of Case 5, where the operator died. Neither ethanol nor drugs of abuse were detected in any decedent.*

No.	Cause of Death	Nature of Accident	Task Performed*
1.	Blunt force injury	Dropped load	Regularly assigned
2.	Blunt force injury	Dropped load	Regularly assigned
3.	Blunt force injury	Run over by crane	Regularly assigned
4.	Blunt force injury	Dropped load	Regularly assigned
5.	Mechanical asphyxia	Tipped crane	Regularly assigned
6.	Blunt force injury	Run over by crane	Not regularly assigned
7.	Blunt force injury	Pinned during maintenance	Not regularly assigned
8.	Blunt force injury	Dropped load	Regularly assigned
9.	Blunt force injury	Pinned during maintenance	Regularly assigned
10.	Thermal burns	Dropped load (molten aluminum)	Regularly assigned

*As determined by the investigation conducted by the Occupational Safety and Health Administration (OSHA).

Case 1—A-27-year-old male non-union worker was atop a kiln at a cement plant that was being razed. The kiln was being cut into sections that were then lowered to the ground by a mobile truck crane. The decedent was fastening a loop of cable to the crane hook, but apparently did not fasten it properly, because when tension was placed on the cable it broke loose, knocking the decedent 30 ft (9 m) to the ground. An OSHA inspection found one serious violation, and the company was assessed a penalty of $80.

Case 2—A 22-year-old male union worker was one of three men knocking out the last tie connecting the mold for a 32 × 14 ft (9.8 × 4.3 m) concrete retaining form that weighed 18 000 pounds (8.2 metric tons). The form was being supported by a tower crane, and once the last tie was removed the crane was going to lift the form to continue work constructing the next floor of the building. The loss of the tie caused the bracket holding the form to give way, and the form fell 72 ft (22 m) to the ground. The decedent's safety line was attached to the form, so he was carried to the ground with the form. An OSHA inspection found four serious violations, and the company was assessed a penalty of $1755.

Case 3—A 34-year-old male union worker was a switchman with one month's experience working with a crane mounted on railroad tracks. The crane operator signaled his intent to back up to the decedent, and the operator saw the decedent working his way around the crane. The operator then guided the crane to its next job before noticing that the decedent was not on the crane. The decedent was found lying across the tracks with his legs amputated at the pelvis. The decedent had been hit by the next car on the track behind the crane. An OSHA inspection found no serious violation, and the company was assessed no penalty.

Case 4—A 31-year-old male non-union radio man with 11 years of experience was working with the operator of an overhead crane. The decedent unhooked a section of steel tubing. It is unknown whether the decedent gave the signal to raise the hook, but the operator next began to raise the hook. As the hook rose it caught on a lathe, and the strain caused the chain supporting the hook to break. A 14 ft (4.3 m) section of the chain fell and hit the decedent in the head, causing multiple skull fractures. An OSHA inspection found

two serious violations, and the company was assessed a penalty of $1000.

Case 5—A 62-year-old male non-union worker had been a crane operator for 20 years. He and his crew were going to drive pilings along an undeveloped stretch of river. The decedent constructed a road for the mobile crawler crane by compacting fresh earth alongside the river. The decedent was driving his crane along the road when the crew signaled that the road was giving way under the left tread. The decedent exited his cab, assessed the situation, and said that he could cut the treads hard to the right and continue. After going 10 ft the crane tipped over, trapping the decedent in the open cab which filled with soft earth. An OSHA inspection found one serious violation, and the company was assessed a penalty of $150.

Case 6—A 42-year-old male was a union switchman working with a crane mounted on railroad tracks. The decedent was riding on a board attached to the crane as it moved to another job at a speed of 4 to 5 miles per hour (6 to 8 km/hour). The decedent fell from the board and was run over by the wheels of the crane. An OSHA inspection found no serious violation, and the company was assessed no penalty.

Case 7—A 29-year-old male non-union worker was hired from a temporary employment service to clean the boom of an overhead crane. The decedent and another man were raised via a platform to clean the boom. The two had finished and started to lower their platform. The crane operator moved the crane, thinking that the cleaners were clear of the crane's path, but they were not, and the decedent was struck by the crane and pinned by the chest against a retaining rail around the platform on which he was standing. An OSHA inspection found three serious violations, and the company was assessed a penalty of $2250.

Case 8—A 47-year-old male non-union worker and another man were hooking a cable to an air compressor so that the compressor could be lifted by a mobile crawler crane. The two men fastened the cable to the lifting lug on top of the compressor, but for some reason a part of the lifting lug had been disconnected. The compressor was lifted approximately 15 to 20 ft (4.6 to 6.1 m) into the air before the lug gave way. The air compressor fell onto the head of the decedent. An OSHA inspection found one serious violation, and the company was assessed a penalty of $2700.

Case 9—A 48-year-old male union mechanic was called to evaluate an overhead crane's boom that was making excessive bearing noise while operating. The decedent was on the crane listening as the operator moved the crane. The operator was unable to see the decedent and moved the crane too near a steel support, crushing the decedent's chest. An OSHA inspection found no serious violation, and the company was assessed no penalty.

Case 10—A 49-year-old male union employee had 20 years experience working at an aluminum plant. The decedent was responsible for attaching four hooks and chains to the lower lifting lugs of a steel vat that contained approximately 17 tons (16 metric tons) of molten aluminum (1400°F, 760°C). After attaching the hooks the vat was lifted by an overhead track crane, but one of the lugs broke and the vat tilted, spilling the molten aluminum into the pit in which the decedent was standing. The skeletal remains were recovered on the day after the accident once the aluminum had cooled. An OSHA inspection found no serious violation, and the company was assessed no penalty.

Discussion

Reports of injury or death related to crane operation in the medical literature are available, but few in number. A study by Lerer et al. looked at the long-term mortality of crane operators (4), but this study was primarily concerned with the natural diseases to which crane operators might be prone. Lerer et al. mentioned that 33 of the 812 deaths in their study were accidental, but no additional details were given. Individual cases are recorded of bronchial rupture (5) in one man and cardiac rupture (6) in another, each case occurring as a result of the individual being struck in the chest by a crane. Häkkinen, working from insurance claims reports, found that the individuals most commonly injured in a crane accident are the workers fastening, guiding, or loosening loads (7). Häkkinen's review was of injuries, but our findings are in keeping with Häkkinen's, for nine of the ten decedents were working outside the cab of the crane when the accident occurred.

Suruda et al. reviewed data obtained from OSHA concerning 502 crane-related deaths and found various types of crane accidents that led to death (see Table 2) (8). The single largest category in Suruda's study was electrocution, accounting for 39% of the deaths. (Electrocution is also a common cause of crane-related deaths abroad; Brokenshire et al. in a study of electrocutions in New Zealand reported that 7 of 95 electrocutions were caused when a crane or the crane's load touched overhead power lines (9).) The 61% of deaths in Suruda's study that were not caused by electrocution were generally a consequence of the great mass of either the crane or its load (57%) or of a fall from a height during a manlift, that is, the crane hook is used as an elevator for a man (4%). Our findings were similar, for blunt force injury caused death in eight of ten cases (see Table 1). In fact, the great masses involved in crane work account for the other two deaths in our study as well. Had the load in Case 10 been solid rather than molten aluminum, that death would have been due to blunt force injury. The mechanical asphyxia in Case 5 was caused by the crane tipping over on a soft surface insufficient to support the crane's weight.

TABLE 2—*Circumstances of injury in crane-related deaths, adapted from Suruda et al. (8).*

Cause of Accident	Number of Deaths	Percentage of Total
Electrocution	198	39
Struck by boom	99	20
Dropped load	65	13
Tipped crane	50	10
Other*	29	6
Struck by moving load	22	4
Fall	21	4
Crushed by counterweight	17	3
Control confusion†	1	0
Sum	502	100

* Includes cases in which OSHA records described circumstances surrounding injury as "other" (24 cases), overloading not related to boom collapse or crane tipping (2 cases), and "insufficient information" (2 cases).

† Operator inadvertently activated the wrong control. (Unlike automobiles, which have a standard location for the brake and accelerator pedals, the position of controls varies from crane to crane and can confuse an operator moving from one crane to another.)

Most crane-related injuries could be prevented by planning prior to the start of construction (1). Such planning should include review of the project, consideration of the appropriate crane or cranes for the job, and a review of specific hazards that might be encountered. Once hazards are identified, then plans can be made to prevent an accident from occurring (1). Planning is a routine part of most jobs involving cranes in Jefferson County, and evidence of this is the lack of deaths due to electrocution in our county over the past 15 years. Nationwide, electrocution is the most common cause of death related to cranes (1,8). Electrical power lines are usually present at any job site in construction where a crane is being used. It is not even necessary for a crane to touch a power line in order for electrocution to occur, for if the boom moves too near the line electricity can arc from it (1). Because humans are incapable of visually judging the distance between a crane boom and a power line accurately, MacCollum suggests that electric utilities remove lines or suspend power to lines that run within a radius 15 ft (4.6 m) beyond the tip of the boom when the boom is lowered to the ground (1). In Jefferson County the practice is to suspend power to lines while a crane is working, a practice with which the power company is happy to comply. Since 40% of deaths related to cranes are caused by electrocutions, and since we have had ten crane-related deaths in Jefferson County since 1982, it is reasonable to assume that the routine practice of suspending power to lines close to a working crane has saved seven lives in the past 15 years.

Despite the success of planning to prevent crane-related electrocutions in Jefferson County, ten crane-related deaths did occur over the course of our study. Proper planning and adherence to the safety procedures that were established by planning could easily have saved the lives of more than half the decedents in our study. In Cases 5, 7, and 9 death occurred because each crane operator failed to recognize the danger that a moment's reflection should have made obvious. In Case 5 proper planning would have dictated the building of a road suitable to support the crane's mass. Proper planning would have prevented each operator from moving his crane blindly in Cases 7 and 9. Other deaths could have been prevented by adherence to safety procedures. In Case 2, a man died because he attached his safety line to the crane's load rather than to an immobile object. In Cases 3 and 6 the assistant was moving about the crane platform or was in a precarious position while the crane was in motion, and each died when he fell from the crane and was run over.

In addition to proper planning and adherence to safety plans formed, we recommend that all crane operators be licensed and certified as such. Many professional workers are required to attain a license and to demonstrate proficiency in their field by achieving and maintaining certification. Despite the complicated nature of crane operation, most governmental bodies in the United States require neither licensure nor certification of crane operators working within their jurisdiction. Nevertheless, licensure and certification of the crane operator involved in a death should be checked as a part of the investigation of any crane-related death, since some companies do require certification of their operators. The benefit of licensure and certification can be seen in Ontario, Canada. Ontario now requires certification of crane operators and reports that during the decade prior to mandatory certification (1969 to 1978) the province had 8.7 construction fatalities per 100 000 workers per year, 3.6 of which were crane-related. From 1978 to 1993, following mandatory certification, Ontario had 4.3 construction fatalities per 100 000 workers per year, 1.4 of which were crane-related (1). We recommend mandatory licensure and certification for all professional crane operators in all jurisdictions.

We also recommend the assessment of larger fines by OSHA for safety standard violations found during investigation of an accident. In our study, the fines paid by the six companies which were cited for serious violations of OSHA standards ranged from $80 to 2700. The threat of a fine of $80 for a serious violation hardly spurs a company to ensure that safety plans are followed by its employees.

Conclusions

In summary, deaths associated with cranes in Jefferson County are most commonly due to blunt force injury. A member of the construction crew working outside the crane is far more likely to be injured than is the crane operator. Neither ethanol nor drugs of abuse contributed to any death in our study. Planning prior to the beginning of any crane job is an essential part of the safe, effective operation of a crane, and in many cases can prevent human error from causing a lethal injury. The suspension of power to electrical lines in the vicinity of a crane while the crane is working, which is a routine part of the plan of all crane jobs in Jefferson County, has saved an estimated seven lives in Jefferson County in the past 15 years by preventing electrocution. The formation of and adherence to a proper safety plan would have saved the lives of at least six of the ten decedents in our study. In addition to planning and safe practice, we recommend the mandatory licensure and certification of crane operators and the assessment of larger fines by the Occupational Safety and Health Administration when a serious violation of OSHA standards is found in an accident investigation.

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References

1. MacCollum DV. Crane hazards and their prevention. Des Plaines, IA: American Society of Safety Engineers, 1993.
2. Shapiro LK, Shapiro HI. Construction cranes. Sci Am 1988;258(3):72–9,122.
3. Crane and Derrick Certification License Requirements, Article 12 (Tower Cranes—Operating Permit and Certification Requirements), §344.70, from California Occupational Safety and Health Regulations Articles 11–13, Title 8 California Code of Regulations (Feb. 1992).
4. Lerer TJ, Redmond CK, Breslin PP, Salvin L, Rush HW. Long-term mortality study of steelworkers: VII. Mortality patterns among crane operators. J Occup Med 1974;16:608–14.
5. Lin MY, Wu MH, Chan CS, Lai WW, Chou NS, Tseng YL. Bronchial rupture caused by blunt chest injury. Ann Emerg Med 1995;25:412–5.
6. Fulda G, Brathwaite CEM, Rodriguez A, Turney SZ, Dunham CM, Cowley RA. Blunt traumatic rupture of the heart and pericardium: a ten-year experience. J Trauma 1991;31:167–73.
7. Häkkinen K. Safety in materials handling. Scand J Work Environ Health 1981:7(Suppl 4):109–14.
8. Suruda A, Egger M, Liu M. Crane-related deaths in the U.S. construction industry, 1984–94. Washington, DC: Center to Protect Worker's Rights, 1997 Oct. Report No.: D2-97.
9. Brokenshire B, Cairns FJ, Koelmeyer TD, Smeeton WMI, Tie ABM. Deaths from electricity. N Z Med J 1984;97:139–42.

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