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REVIEW ARTICLE

THORACIC INJURIES IN URBAN INFANTS AND CHILDREN

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Trauma is an integral part of our society. That truth is reflected in the fact that about 100,000 children die of some form of injury in the United States every year. Since there is great need for prevention of these deaths the nature and distribution of injuries in children is of primary interest. Study of thoracic injuries is particularly important since they are a substancial source of crippling morbidity and mortality especially when combined with other injuries.

In a study of 51 children with thoracic trauma reported by Levy[1] at Tulane University, sixteen children had concommitant skull fractures, nine had ruptured spleens, and thirty-eight had long bone fractures. There was an overall mortality rate of thirty percent (30%) in this series primarily due to associated head injuries. We set out to study the epidemiology of thoracic injuries in children in a major urban area, Chicago. In order to obtain an adequate sample for study, we obtained permission to review the injuries brought into five representative hospitals in the northern half of Chicago, (Fig. 1), (Table 1).

The combined study represents a sample of pediatric thoracic injuries derived from hospitals of 2017 beds with a combined annual emergency room admission rate of 125,000 injuries per year. Each hospital had injuries characteristic of sociologic conditions in the area it served. The combined experience, however, cut across all segments of society so that this series is representative of the general metropolitan experience with chest trauma in children. The 424 cases represented an incidence of 0.35 percent of all emergency room admissions.

Of the 424 cases, twenty percent (20%) were injuries associated with birth; twenty-nine percent (29%) resulted from *aspiration of foreign bodies;* 21. 93% were caused by *blunt trauma to the chest;* 18.16% resulted from *penetrating injuries to the chest;* three percent (3%) were *compression fractures of the vertebral column;* and seven percent (7%) were the result of *burns to the thoracic wall.*

The types of injuries sustained were closely allied with the patient's age. In the newborn period, chest injuries usually resulted from birth trauma. Somewhere about the third to the fifth year, there is a peak in the incidence of foreign body aspiration. At the end of the first decade of life, when the children are small, tender, difficult to see and easily subjected to blunt physical forces, there is a high incidence of blunt injuries to the chest. Finally, as the children grow older and become teenagers, there is a significant increase in the incidence of penetrating wounds to the chest. Most of these latter injuries occur in the savage environment of the ghetto. Compression injuries to the

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vertebral column occur when the child is able to engage in vigorous sports. Burns in the chest can occur at any age, but prominently are noted in the toddler where self-inflicted accidental burns occur from spillage of hot liquids upon the child.

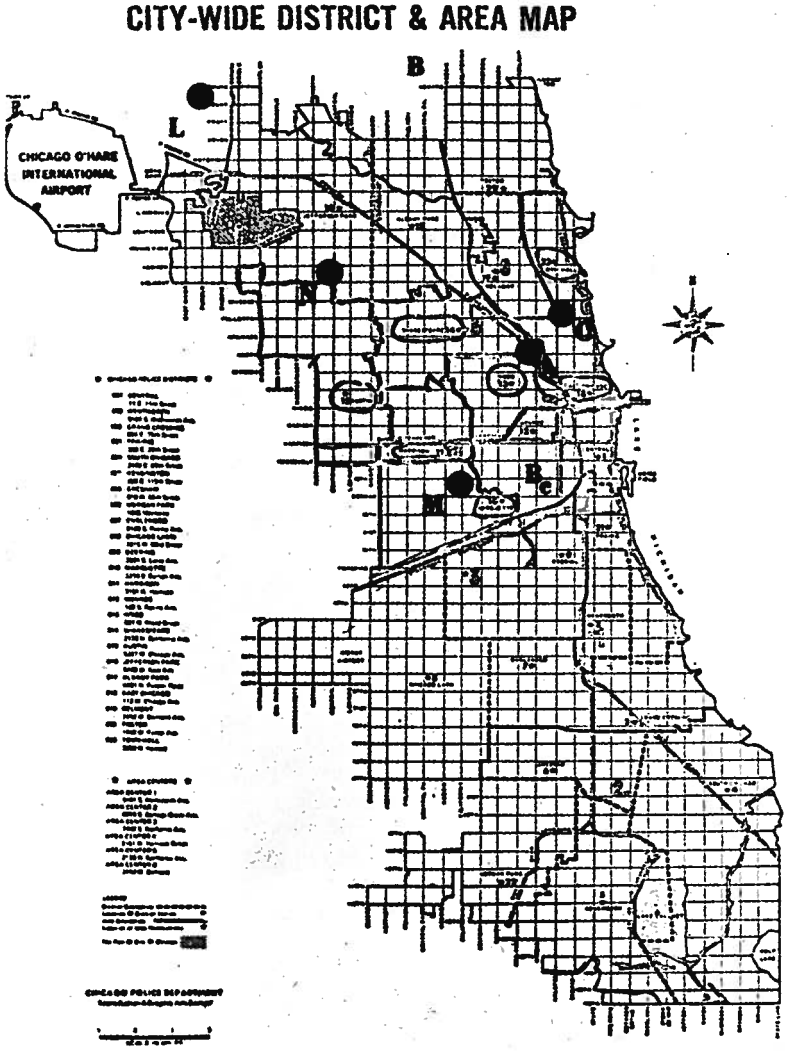

Fig. 1 — *The five institutions included in our study:* Lutheran General Hospital [L] *(675 beds), located near a super highway and having a high-risk newborn nursery;* Children's Memorial Hospital [C] *(254 beds), a major pediatric diagnostic and therapeutic hospital for the area;* Mount Sinai Hospital [M] *(450 beds), a major teaching hospital for Rush Medical College, located near an urban ghetto as well as a major limited access superhighway;* Augustana Hospital [A] *(302 beds), located in the near north side close to downtown Chicago; and* Northwest Hospital [N] *(336 beds), located in a northwest blue collar, factory and small business area. B and Bc represent burn centers servicing the area. These severe burn cases were not available for inclusion in our study.*

Table 1
Case distribution: Thoracic injuries in urban infants and children

	Median Age of Occurence	Cases	Percent
Birth Injuries	Newborn period	85	20.05%
Foreign Bodies	3- 5 years	125	29.48%
Blunt Injuries	6- 9 years	93	21.93%
Penetrating Injuries	14-18 years	77	18.16%
Gunshot Wounds, 41=(9.67%)			
Stab Wounds, 36=(8.49%)			
Compression of Dorsal or Thoracic Vertebrae	10-14 years	13	3.07%
Chest Burns (Mild, Moderate)	3- 5 years	31	7.31%
		424	100%

THORACIC INJURIES RESULTING FROM BIRTH TRAUMA

Trauma incident to the birth process can occur from obstetrical manipulation, severe respiratory effort as the newborn passes through the birth canal, severe coughing paroxysms or vigorous attempts at resuscitating an obtunded newborn, (Table 2). A substantial number of infants in our series (42 or about 10% of the total number) were born with *fracture of the clavicle.* Generally there was no pneumothorax and no apparent distress. Sometimes there was obvious clavicular deformity. Occasionally the diagnosis is made by chest roentgenograms. Operative intervention was not required. The fragments were close enough to respond to conservative support.

The remaining 53 patients developed pneumothorax, pneumomediastinum, subcutaneous emphysema or interstitial emphysema resulting from coughing paroxysms or vigorous inhalation therapy. In most of these patients it was only necessary to provide supportive observation and care and the entrapped air was eventually absorbed. Seven of these children, however, had multiple injuries (including cerebral injuries) that were life threatening (Item 5, Table 2). Four had rupture of the spleen or liver from vigorous attempts at resuscitation. Several were severely obtunded from premature neonatal asphyxia or cerebral concussion. (Items 3, 4 and 5, Table 2). A number had respiratory disease of the newborn which greatly complicated the postnatal care of the infant.

Table 2
Trauma associated with resuscitation at birth

	N.° Cases	Deaths	% of Series
1. Fractured Clavicle without Emphysema	42	(0)	49.4 %
2a. Normal Term Newborn with Pneumothorax or Mediastinum	8	(0)	9.4 %
2b. Normal Term Newborns with Subcutaneous Emphysema	5	(0)	5.98%
3a. Prematurity with Respiratory Disease Syndrome (R.D.S.) and Pneumothorax or Pneumomediastinum	9	(3)	10.6 %
3b. Prematurity and R.D.S* with Interstitial Emphysema	5	(1)	5.9 %
4. Severe Neonatal Asphyxia at Birth Requiring Resuscitation: Pneumothorax or Pneumomediatinum Resulting	9	(6)	10.6 %
5. Multiple Factors, including Prematurity, Asphyxia and Birth Injury	7	(5)	8.2 %
Total	85	15	100%

* R.D.S. represents Respiratory Disease of the newborn.

In patients with significant pneumothorax chest tube drainage with water seal was inserted, to facilitate expansion of the lung. Airway was maintained by endotracheal intubation for brief periods of time. None of these patients required tracheostomy, (Fig. 2).

Curiously, three older children were encountered during our study who had developed pneumo-mediastinum and subcutaneous emphysema secondary to severe coughing paroxysms from bronchial asthma. These children responded to conservative support, and treatment of the asthma attack. The extravasated ais was absorbed, (Fig. 3).

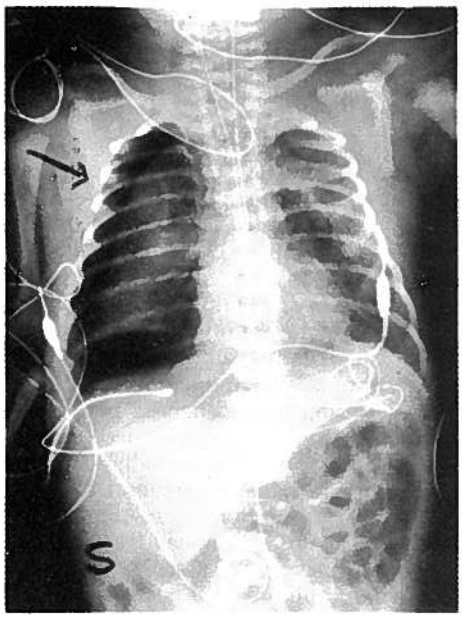

Fig. 2 — *Chest roentgenogram of newborn with stippling of the lung characteristic of respiratory disease syndrome (R.D.S.). The newborn also developed pneumothorax requiring chest tube drainage to relieve hypoxia.*

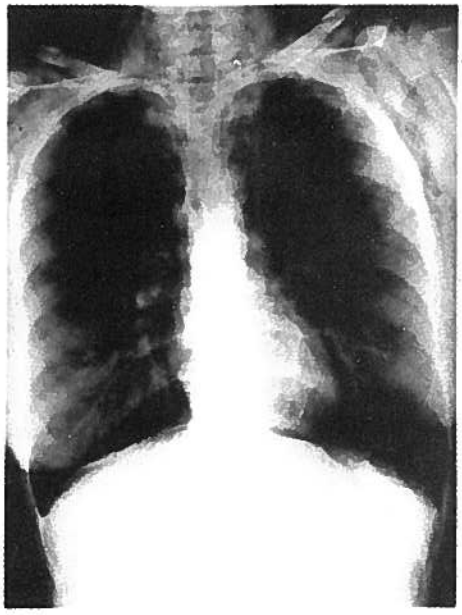

Fig. 3 — *Chest roentgenogram showing pneumomediatinum following severe paroxysm from bronchial asthma. The extravasated air was absorbed spontaneously.*

PENETRATING INJURIES OF THE CHEST

The constant internecine warfare among teenagers and young adults in the urban ghetto yields a substantial number of gunshot wounds and stab wounds (Table 3). Most of them, fortunately, are limited to damage of the lung parenchyma. With closed tube insertion and attachment of water seal drainage bottle usually is sufficient to expand the injured lung, restore pulmonary function, and evacuate the pleural space. If persistent intrapleural hemorrhage is present or an organized hematoma results, immediate or delayed thoracotomy may be necessary and can be life-saving. The compelling danger in such injuries is the possibility of injury to mediastinal organs or penetration of the weapon or missile through the chest and into the upper abdomen. Location of the wound and its trajectory are important aspects of assessing the injury and require excellent surgical judgement. If there is any question of penetration into the abdomen, laparotomy is mandatory. Many lives have been saved by immediate thoracotomy in the presence of acute continued intrathoracic hemorrhage.

Table 3
Treatment methods of penetrating wounds

	Stabs	%	GSW	%	Total	%
Conservative No Laparotomy, No Thoracotomy, No Tubes; Thoracentesis in 2)	15	41.67	3	7.32	18	23.37
Closed Thoracotomy Drainage	11	30.56	15	36.59	26	33.37
Closed Tube Drainage & Laparotomy	7	19.44	15	36.59	22	28.57
Closed Tube Drainage & Other Operations	1	2.78	4	9.76	5	6.49
Laparotomy and Open Thoracotomy	1	2.78	1	2.44	2	2.60
Open Thoracotomy only	1	2.78	3	7.32	4	5.19
Total	36		41		77	100%

GSW=Gunshot wounds of chest
Stabs=Stab wounds of chest

If there is any suggestion of entry into or across the mediastinum, a barium swallow is indicated to rule out injury of the esophagus. Mediastinal emphysema suggests injury to either the tracheobronchial tree or the esophagus. Neck vein distension, pulsus alternans, shock and distant cardiac sounds, plus a wound in the appropriate area, suggest cardiac tamponade and indicate diagnostic aspiration of the pericardium or immediate exploratory thoracotomy (Fig. 4 and 5).[2]

We tend to use immediate open thoracotomy much more today than we did in years past. This change in policy should reduce mortality because of prompt control of potentially dangerous hemorrhage and improved restoration of function before extensive deterioration of the injured patient.

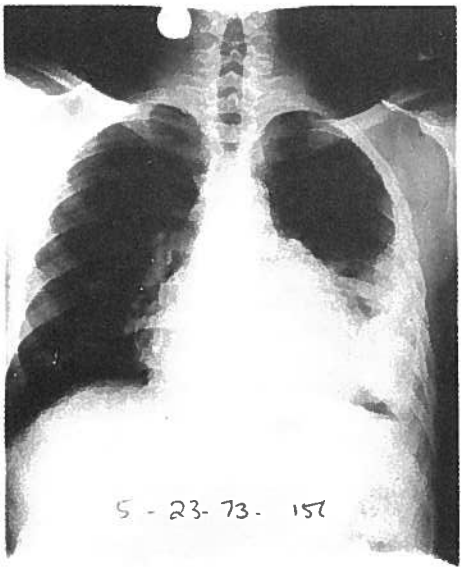

Fig. 4 — *AP and lateral chest roentgenograms of a teenage boy shot in the left axilla. The missile has traversed the mediastinum. Esophagram failed to demonstrate any injury to the esophagus. There was no mediastinal emphysema. Because of the location of the bullet, he was explored through a right thoracotomy. The bullet was lodged between the right main stem bronchus and the right main pulmonary artery. It had penetrated the posterior wall of the right main pulonary artery, which was repaired. The left pleural hematoma eventually resorbed.*

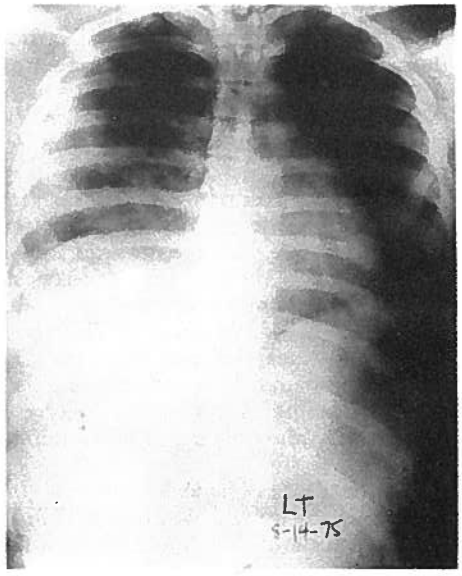

Fig. 5 — *Gunshot wound of right side of chest with a soft, hollow-point missile. Wound of entry was under the right areola. The bullet's trajectory was in a straight anterior-posterior plane. Under observation, the boy developed signs of localized peritonitis in the right upper abdominal quadrant. He was explored. Substantial hemorrhage was encountered. A badly lacerated penetrating wound of the right lobe of the liver was excised. Severely damaged right lower of the lung was also debrided.*

BLUNT INJURIES TO THE CHEST

Most of these injuries in children occur from automobile incidents. Over half of these cases (Table 4) were related to auto collisions in which the child was a passenger (or driver, if older) or incidents in which the child was inadvertently struck by a passing vehicle. Falls and vigorous sports, physical beatings and child abuse also contributed.

Traumatic multiple rib fractures with flail chest leading to respiratory difficulties are rare in young children, probably because their thoracic cage is so elastic that it can absorb considerable bending force. In older children, however, multiple rib fractures and flail chest may occur. Young patients subjected to severe compression injuries of the thorax develop a syndrome known as *Traumatic Asphyxia*[3], which occurs when the chest wall is severelly compressed while the glottis is closed, and results in increased pulmonary and systemic venous pressure and extravasation of blood into the lung parenchyma and petechial hemorrhages over the face and upper chest. The full extent of pulmonary damage may not be immediately apparent. Clinically, the child may appear well and his chest roentgenogram on admission may not be alarming. Progressive asphyxia manifests itself within the next two or three days, and repeated chest roentgenograms show fluffy or linear densities in the lung fields, indicative of perivascular and peribronchial hemorrhages. There may be increased respiratory effort combined with clinical signs of hypoxemia, including significant changes in the patient's arterial blood gases. The children may require respiratory support including endotracheal intubation, cortisone, antibiotics, trasfusion therapy and other supportive measures such as humidity and pain relief to encourage coughing and removal of pulmonary secretions.

Look for pulmonary contusion in any child sustaining severe blunt trauma to the thorax even though no fractured ribs are present. Multiple rib fractures, if present, are a strong indication that severe trauma has occurred, *especially when there is an associated fracture of the clavicle or the first rib. This combination, in our experience, is a certain harbinger of difficult pulmonary problems in the immediate post-traumatic management of the injured child.*

Another area of serious concern in blunt chest trauma is the potential occurrence of rupture of the tracheobronchial tree.[4] Persistent pneumothorax which does not respond to tube drainage, or extensive mediastinal or subcutaneous emphysema suggests rupture of the bronchus or trachea. Air may also dissect into the peritoneal cavity or the pericardium. However, these findings are not always present. Ruptured bronchus may be silent and unsuspected. The loose peribronchial tissues may maintain continuity of the bronchial wall and limit air leak, even though the integrity of the bronchial lumen is impaired by separation of the ends of the ruptured bronchus. Oftentimes, the primary finding is persistent atelectasis of the lung distal to the site of rupture.[5] Occasionally, the only significant finding immediatelly following trauma is hemoptysis (Fig. 6).

The most dependable method for establishing a diagnosis of rupture of the bronchus is by immediate diagnostic bronchoscopy. Successful repair has been reported from three months to eight years following initial injury.[6, 7, 8] Leape reported a six centimeter separation of the left main stem repaired immediately following the trauma.[9] Repair is accomplished by end-to-end anastomosis with non-absorbable sutures. The anesthesiologist must intubate selectively the uninjured contralateral bronchus in order to maintain adequate ventilation during the operation. Post-operatively, periodic follow-up bronchoscopy is indicated to evaluate and, if necessary, to dilate strictures at the site of repair.

Rupture of a leaf of the diaphragm has been reported in association with blunt trauma to the thorax.[10-12] Roentgenograms of the chest may demonstrate stomach or loops of bowel above the level of the diaphragm, Because of severity of the trauma

required to produce rupture of the diaphragm. concommitant injury to upper abdominal organs, especially stomach, liver, spleen and bowel, also occurs because of related abdominal organ injury. Acute diaphragmatic rupture should be repaired through a laparotomy incision, so that the abdominal organs may also be inspected thoroughly and repaired. ***Pulmonary injury can usually be managed by closed thoracotomy, but we have, in our experience, also performed an additional thoracotomy when the occasion warranted inspection and repair of injured thoracic organs*** (Table 4).

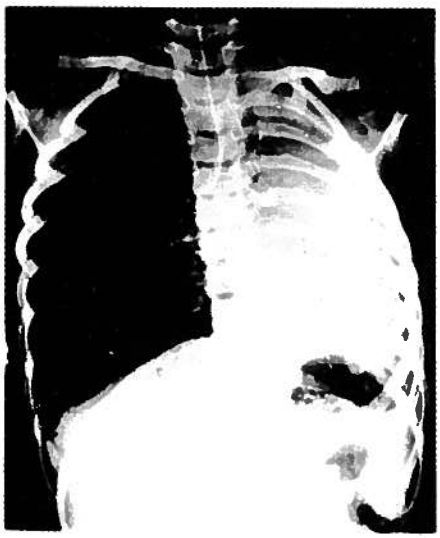

Fig. 6 — *Roentgenogram of child who was referred for evaluation of chronic atelectasis of left lung. She had been involved in an automobile collision several months before referral. Bronchograms demonstrated a transected left main stem bronchus.*

Table 4
Types of blunt trauma

		Total	Percentage
Autos:			
Driver-Passenger	26		
Victim (Hit)	26	52	55.9%
Vigourous Sports (Football, Hockey, Skiing, etc.)		14	15.1%
Falls, crushing, etc.		18	19.3%
Beatings (By peers)		5	5.4%
Child Abuse (By parents)		4	4.3%
Total		93	100%

INGESTION OR ASPIRATION OF FOREIGN BODIES

The small child between the ages of three and six years has a special set of trauma problems. Because he begins to walk, the child becomes very active and mobile. It is in this age group that he can wander about the house and find numerous trinkets and small objects that invariably are placed in his mouth. Invariably some of these small items are aspirated and end up wedged in the trachea or the esophagus, (Table 5).

Table 5
Foreign bodies: Distribution

Esophagus		Trachea	
Coins	46	Peanuts	10
Nails, Pins, Metal, etc.	13	Nails, Pins, Metal, etc.	7
Medals	9	Popcorn	6
Meat (post TEF)	8	Other Non-Opaque For. Bodies	6
Non-Opaque Foreign Bodies	6	Chain Pieces	2
Buttons	5	Shell	1
Bones	3	Bones	1
Chain Pieces	2		
Total	92	Total	33

Post TEf: Following repair of tracheo-esophageal fistula

In our study we encountered 125 such patients. They were about 3-1 divided between the esophagus and the trachea. The foreign bodies in the esophagus posed no immediate threat to the patient's life although if there are sharp points or jagged edges there is danger of perforation of the esophagus. We are fortunate in this city to have excellent pediatric endoscopists who are very adept at removing these objects successfully. We did have one case, however, in which an aspirated beer can top perforated the esophagus and caused a chronic tracheo-esophageal fistula that later had to be surgically repaired. In most instances endoscopic removal of the esophageal foreign body was sufficient.

When the foreign body is aspirated into the tracheo-bronchial system a more urgent problem develops. Usually the child develops stridor or wheezing and, if the object is large enough, acute respiratory obstruction can lead to asphyxia and death. We have had one such case in which the child aspirated a small coin that rotated and obstructed his airway. The child was dead on arrival to the emergency room. In tracheal foreign bodies it is essential that emergency room personnel, if they find that they cannot wait for the skilled endoscopist to arrive, be able to intubate or bronchoscope the patient or do a tracheostomy in order to try to save the patient's life.

Although foreign bodies can generally be removed by endoscopy they are extremely dangerous because their effects are unpredictable and potentially life threatening. In one patient (Fig. 7), a sharp tack was aspirated into the right bronchus which sustained a long laceration and produced a severe right pneumothorax. The patient then coughed the tack into the opposite (left) main stem bronchus. Closed tube thoracotomy water seal drainage was introduced, but the tension pneumothorax could not be controlled in this fashion. Since the patient was in respiratory collapse, immediate right thoracotomy was done under endotracheal intubation. The laceration extended up to the carina and fortunately the tack could be removed with a long gasping instrument. The laceration was repaired and the patient survived without any demonstrable sequellae.

It is clear that the best treatment for these tragic incidents is prevention, yet these children are very active and these events can occur quickly. Our endoscopists particularly emphasize the dangers of popcorn and peanuts. Delightful as these vegetable compounds are to eat, they can be easily aspirated into the tracheo bronchial tree and, because they are not radio opaque, they are difficult to detect. Further, as is now well known, they deteriorate in the bronchi and can produce chronic bronchial stenosis and atelectasis which can ultimately require pulmonary excision.

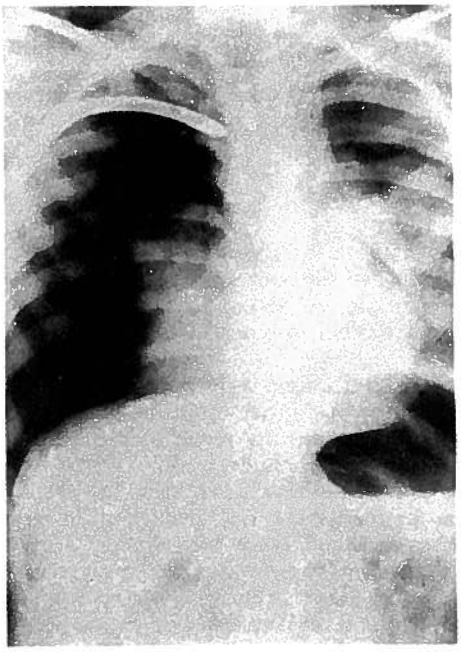

Fig. 7 — *Chest roentgenogram of the boy who aspirated a sharp tack, seen lying in his left mainstem bronchus. The tack first lacerated the membranous portion of the right bronchus and produced a right tension pneumothorax. The boy then coughed it into the left bronchus (see text).*

COMPRESSED FRACTURE OF THE VERTEBRA

It was interesting that in this series, there were a number of cases in which the child fell in such a way that it sustained one or more compression fractures of the thoracic vertebrae. Usually, the fifth, sixth, and seventh dorsal vertebra were involved. The type of fall consisted of either falling on the buttocks from a height of three to six feet, falling on the back near the base of the neck, or falling upon the head while tumbling, falling from some type of athletic apparatus, or falling from a horse. The fall had to exert substantial pressure along the long axis of the vertebral column, but it could also result from *jackknifing* of the thoracic column. In two patients, the severe muscular contractions resulted from electrical currents which caused severe jerking motion of the vertebral muscles and produced compression fractures of the vertebra. In the other injuries, the compression fractures resulted from direct blunt trauma with forces exerted along the long axis of the vertebral column.

BURNS OF THE CHEST

This series had an extremely small number of burns to the chest. This paucity of burn cases is an indication of the efficient method of which burns are transported to the well developed burn centers in the metropolitan Chicago area. (See B and Bc, Fig. 1). The burns in this series represent relatively modest burns that responded readily to treatment with antibiotics and dressings and were not severe enough to require exten-

sive treatment for shock. All of the patients responded well to therapy and study of these burns is representative of a sampling of the causes for which burns occur in children — namely, the spilling of hot liquids incident to cooking in the kitchen, accidental electrocution from electrical wires or connections, or accidents in the bathtub when children inadvertently or perhaps maliciously are immersed in hot water.

COMMENT

This study of cases of thoracic injuries in urban infants and children covers the most common types of such cases encountered but obviously might not include the rare miscellaneous case. For example, we had one case of ruptured aorta following severe automobile trauma. There are other rare miscellaneous lesions that were obviously not encountered.

A number of lesions — foreign body aspiration, burns from spillage of hot liquids, and vertebral compression injuries might be judged unique to the activities of children. However, most injuries are the result of the environment inherent in our society and are found in adults and children alike.

In general, most surveys dealing with thoracic injuries list both adults and children, indicating that the treatment in both adults and children is similar. It is essential, however, to give due consideration to the fact that children are smaller in size and require more detailed attention to the physiologic parameters that we use in monitoring surgical therapy in general. It is also equally important for the surgeon to recognize that in all of his instrumentation and maneuvering with children, he must exercise a great deal of gentleness and patience since vigorous instrumentation or motion is likely to result in injury if it exceeds the physical tolerance of the children that are being treated.

RESUMO

Os Aa. acentuam a maior frequência dos vários tipos de traumatismos torácicos seguindo as diferentes etiologias e idades dos doentes. Assim, realçam os traumatismos resultantes do parto, os torácicos fechados, as feridas do tórax. Fazem também uma menção especial à aspiração e deglutição de corpos estranhos estabelecendo a comparação entre os traqueo-brônquicos e os esofágicos. Finalmente fazem referência às fracturas da coluna e às queimaduras.

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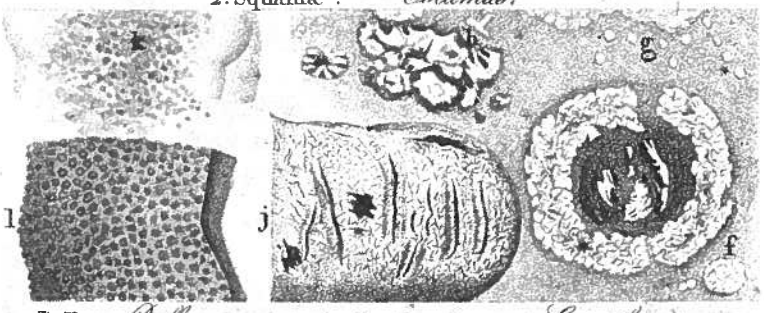
1. Papulæ. *Papulas.*

2. Squamæ. *Escamas.*



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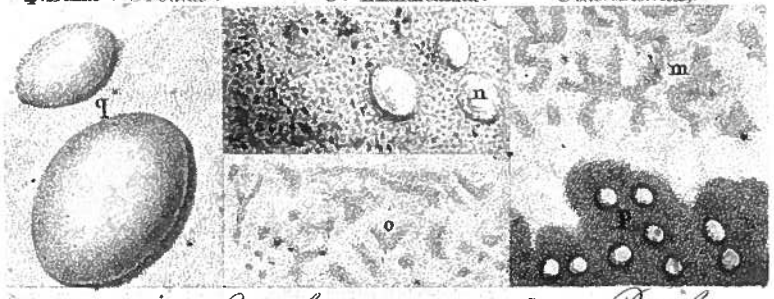

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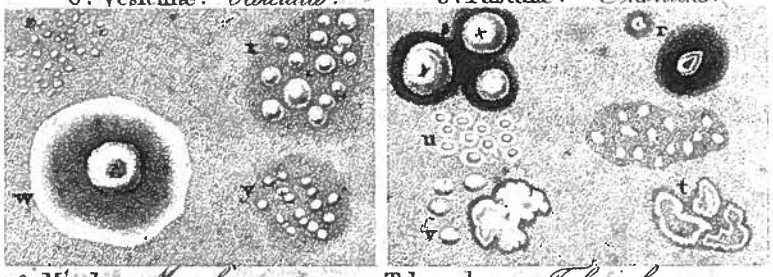

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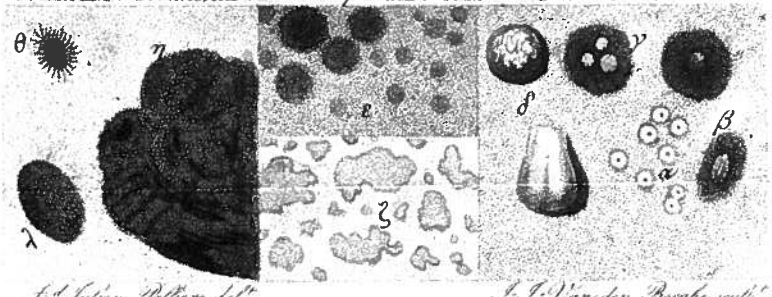

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