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Upper Limb Injuries due to Tumble Dryer Trauma in Children. Classification and Therapeutic Recommendations

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Summary

Every year, emergency rooms at mayor healthcare facilities receive a large number of children suffering from upper limb injuries due to tumble dryer trauma. Pediatric orthopedic surgeons consider these injuries to be a nosological entity with the proper name of “dryer arm”.

Objective

The purpose of this study is to provide a classification system for these injuries, which will allow to create a therapeutic algorithm. The basis for these recommendations is the result of the experience acquired during fifteen years of practice in five different hospitals.

Material and Method

Retrospective observational and epidemiological study. All medical records dating from January 2003 until January 2019 associated with patients suffering from upper limb injuries by vertical tumble dryers were reviewed in five different hospitals. A score was designed for each injury, allowing to classify the patients' injuries into mild, moderate and severe.

Results

The series had 77 cases. The average age was 4 years old (1-14). Gender: 42 males and 35 females. Average follow-up period: 3.2 years. Six patients were considered mild, fifty-four moderate and seventeen severe. 18% (14) of the cases presented some long-term physical damage.

Conclusions

These injuries, largely unknown to the general public, are often complex and can leave serious long-term physical damage. A management algorithm facilitates decision-making for orthopedic surgeons. In this way, it will be possible at least in theory to prevent complications derived from an inadequate initial management.

Level of Evidence. IV

Key words: dryer arm; upper limb injuries; children; classification; algorithm

Introduction

Every year, emergency rooms at mayor healthcare facilities receive a large number of children suffering from upper limb injuries due to tumble dryer trauma. Pediatric orthopedic surgeons consider these injuries to be a nosological entity with the proper name of “dryer arm”. In Argentina, it is commonly known as “KOH-I-NOR arm”, in reference to the most popular tumble dryer brand since the 80's. These injuries, largely unknown to the general public, are often complex and can leave serious long-term physical damage ⁽¹⁻⁸⁾. These injuries happen after the child introduces his hand, and consequently, his upper arm into the functioning tumble dryer ^(5,6).

The purpose of this study is to provide a classification system for these injuries, which will allow to create a therapeutic algorithm. There is a vast amount of literature regarding household accidents during childhood ⁽¹⁻⁸⁾, but it is not specifically connected with the purpose of this study. The basis for these recommendations is the result of the experience acquired during fifteen years of practice in five different hospitals, the collaboration between these hospitals and a significant casuistry.

Material and Method

Retrospective observational and epidemiological study. All medical records dating from January 2003 until January 2019 associated with patients suffering from upper limb injuries by vertical tumble dryers were reviewed in five different hospitals. The variables studied in this research were: age, gender, affected limb, type of humerus and forearm fracture, both following the AO/ASIF classification for pediatric fractures (9, 10). For the supracondylar region of the humerus,

Gartland (11) classification was used. Associated lesions, treatment complications and long-term damage were taken into account.

Criteria of inclusion consists of:

- Skeletally Immature Patients with injuries to one upper limb due to household tumble dryer trauma.
- Minimum follow up period of 12 months.

Criteria of exclusion consists of:

- Skeletally Immature Patients with severe injuries to the upper limbs caused by any household appliance other than tumble dryers.
- Patients presenting long-term damage associated with these type of injuries, who had been initially treated in a different healthcare center.
- Intermittent follow up or follow up during less than 12 months.

A score was designed for each injury, allowing to classify the patients' injuries into mild, moderate and severe. The score ranges from 1 to 7, according to the severity of the injury. The score has nominal value, not cumulative. Table 1

- Soft tissue trauma to the upper limb without bone injury, 1 point.
- Upper limb segment fracture without displacement, 2 points.
- Upper limb segment fracture with displacement, 3 points.
- Upper limb fracture combining two different segments, or two different areas in the same segment (Epiphysis and Diaphysis, for example) with at least one displacement, 4 points.
- Exposed fracture of any kind, 5 points.
- Compartment syndrome, 6 points.

- Traumatic amputation of the upper limb, 7 points.

This score allows to classify the patients' injuries into:

- Mild (type I) Score 3 or lower, outpatient management.
- Moderate (type II) Score 3-4, average in-hospital stay was 24-48 hours, surgical management.
- Severe (type III) Score 5 or higher, potential life-threatening injury, potential limb viability or function loss, average in-hospital stay was over 48 hours. Complex surgical management.

Results

The criteria of inclusion was met by 88 cases, out of which 11 were excluded due to lack of appropriate follow up. The series had 77 cases, Table 2. Average age was 4, between 1 to 14. 42 males and 35 females. 40 right side injuries. 37 left side injuries. Fractures, Table 3. Humeral injuries: 67. Diaphyseal injuries: 54, out of which 29 were 12-D/5.2 figure 1 and 25 12-D/5.1 figure 2.

In the elbow area, 13 were complete, 9 were supracondylar fractures Gartland III and 4 fractures of the epicondyle. Four patients presented humeral diaphyseal fractures combined with fractures to the elbow area. 77 complete fractures to the forearm area. 63 diaphyseal fractures, out of which 35 were 22-D/5.1, 18 were 22-D/5.2, 6 were 22-D/4. Two greenstick cases were 22-D/2. One greenstick ulnar fracture 22u-D/2.1 figure 1. Only one 22u-D/5.1 case. Ten cases in metaphyseal distal area, 7 23-M/3.1; 2 23r-M/3.1 one case (torus) 23-M/2.1.

Twelve patients with exposed fractures, out of which 5 were humeral fractures, 4 presented forearm fractures and 3 presented combined fractures. Out of the 77 patients in this series, 71 (92%), were taken to the OR during initial management. The treatments for the fractures were varied. Surgical debridement was performed on all exposed fractures (15) *figure 3*. Stabilizing/Fixation methods *figure 4*. 144 fractures in 77 patients. Humeral diaphyseal fractures: 24 reductions and Velpeau cast, 17 intramedullary percutaneous retrograde nailing using Kirschner wires going through the external condyle, 7 cases with unilateral external fixator, 5 cases with flexible intramedullary titanium nailing. Supracondylar fractures: 9 nailing fixations. External condyle fractures: 4 nailing fixations. Diaphyseal forearm fractures: 32 reductions and cast, 23 reductions and intramedullary nailing, 6 cases with external fixation and 2 cases of flexible intramedullary nailing. Wrist: 6 reductions and nailing, 3 cases in which both bones were nailed. Reduction and cast in 3 cases.

Four patients in this series developed upper limb compartment syndrome (5%), all of them presented floating elbow with closed fractures. Two patients suffered from traumatic amputation of the upper limb, at the 1/3 region of the arm. Both cases were successfully reattached, *figure 5*.

Based on the score, 6 cases were considered mild or type I. All cases were solved with outpatient management, without visiting the OR. 54 cases were considered mild or type II. 17 cases were considered severe or type III *table 2*.

18 % (14) of the cases presented some long-term damage. Nerve lesions: 9% (7). Five patients presented radial nerve permanent paralysis. Only two cases

were reviewed for more than eight months after the initial injury. A surgical neurolysis was performed on one case presenting ulnar nerve paralysis. The result was unsuccessful. One case presenting median nerve paralysis had a partial recovery. As regards fractures, 4 cases presented malunions, two in the forearm and 2 in the humerus. One case presented pseudoarthrosis in the fracture of the humerus and another case in the fracture of the ulna *figure 6*. This case also presented a radio-ulnar synostosis with an ulnar deviation of the wrist *figure 6*.

Discussion

What do we call “tumble dryer arm”? It’s a type of home accident suffered by children. These injuries happen after the child introduces his hand, and consequently, his upper arm into the functioning tumble dryer. The mechanism of the injury is the result of torsion and attrition. Patients usually present multiple fractures to the upper limb, compromising forearm and arm in most cases. There have been reports of injuries in hands, shoulders, core or face ⁽¹⁻⁸⁾. Injuries to soft tissue are the result of exposure to fractures. Vascular or nerve lesions occur less frequently. In severe cases, traumatic amputation of the upper limb is likely to occur. These type of accidents have been reported in several studies over the years ⁽¹⁻⁸⁾. In 1998, Groiso Jorge A. MD, and collaborators published an article in ARCH ARG PEDIATR Childhood accidents, the tumble dryer disease ⁽⁶⁾. As a result of this article, the Ministry of Commerce and Industry issued Resolution

1655/98, establishing new safety standards for the manufacturing of tumble dryers in this country.

Six cases were attended in just a month. Five were injuries to the upper limb and one case presented craniofacial trauma ⁽⁶⁾. Epidemiological aspects, circumstances in which these accidents occur and technical characteristics of these appliances were taken into account. Many authors have provided us with valuable insight in order to prevent these type of accidents. This study describes the amount of cases presented in the orthopaedics service with these type of injuries. According to a survey carried out over the last ten years, 30 patients suffering from these type of injuries have been treated.

One famous phrase stands out: "Therefore, we can not consider this problem as a mere accident occurring out of neglect, we are faced with a new phenomenon, a new nosological entity, an epidemic even" ⁽⁶⁾. Unfortunately, nowadays, 22 years later, more cases of "tumble dryer disease" are being treated.

This study presents a significant casuistry, 77 cases during a 15 year period. It describes the type of injuries, treatments performed, complications and long-term physical damage in detail. In this series, 18% of the patients presented some long-term physical damage, which could have been prevented by adequate initial management in most cases. In spite of having applying surgical management in Pediatric Orthopaedics more frequently, there is still some degree of controversy regarding orthopaedics management in fixations. The purpose of this study is to provide a classification system and management guidelines for these injuries. The basis for these recommendations is the result of the experience acquired during fifteen years of practice in five different hospitals *figure 7*.

Type I injuries: immobilization, pain management, clear alarm and control pattern in the first 48 hours. Safe outpatient management.

Type II injuries: in-hospital stay. Patients may present one displaced fracture. In this case reduction under general anesthesia is advised. The use of image amplifiers and immobilization with a cast is also recommended. Patients may also present upper limb, arm and forearm fracture (floating elbow) combining two different segments, or two different areas in the same segment with at least one displacement *figures 1, 2, 3 y 6*. In this case reduction under general anesthesia is advised. The use of image amplifiers and arthrodesis is also recommended, as well as intramedullary percutaneous retrograde nailing using Kirschner wires or flexible titanium elastic nails going through the external condyle for humeral and forearm fractures.

Type III injuries: These injuries are severe, *figures 3 and 5*. They require extended in-hospital stay. Patients may present: exposed fractures, compartment syndrome or traumatic amputation. All exposed fractures require surgical debridement according to recommendations ⁽¹²⁾. As regards fixation, authors recommend Gustilo I for exposed fractures management, the same management recommended for type II injuries. As regards exposed fractures, Gustilo II and III. Humeral diaphyseal with external fixation. Regarding forearm open fractures, reduction with cast is advised for treatment. In case of exposed wrist fractures, bicortical-transfocal fixation is advised. In cases where both segments of the upper limb present severe fractures, external fixation is advised *figura 3*. The use of fixation in floating elbow fractures is not disputed since it is highly successful ⁽¹³⁻¹⁵⁾. The worst possible complication in floating elbow fractures is the occurrence of compartment syndrome. In this series, four cases of closed floating elbow

fractures presented compartment syndrome. Blakemore et al.⁽¹³⁾ presented 7% compartement síndrome in the “floating elbow” series. Navarro Vergara ⁽¹⁵⁾ studies report an average of 8,3% compartment syndrome cases in floating elbow in children. In case of compartment syndrome, a toilette must be performed immediately ⁽¹³⁻¹⁵⁾. In traumatic amputations of the upper limb, reattachment must always be attempted as long as it is viable, since reconstructive alternatives are scarce and usually unsuccessful, including prosthetic rehabilitation ^(16,17) *figure 5*.

Why do these injuries occur?

Household tumble dryers are widely used by the general population. Small children may come in contact with the tumble dryer handle very easily because of its height, so these accidents are likely to happen from the moment children start learning how to walk. They imitate the movements performed by adults when handling clothes or just introduce their hands, and consequently their upper limb ⁽¹⁻⁸⁾ out of curiosity. By spinning at a great velocity, (as much as 2800 RPM), the upper limb is instantly wrapped in the clothes inside the tumble dryer and is subjected to a great centrifugal torsional force ⁽¹⁾. Security systems in tumble dryers tend to be manipulated and altered by adults so that the appliance can continue functioning, even if some component is damaged. These accidents can be prevented mostly by educating the general public.

Conclusions

These injuries, largely unknown to the general public, are often complex and can leave serious long-term physical damage. A management algorithm facilitates decision-making for orthopedic surgeons. In this way, it will be possible at least in theory to prevent complications derived from an inadequate initial

management. Even though security systems in household appliances have been improved on, patients suffering from “tumble dryer arm” are still being reported with an alarming frequency.

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Table 1. Score used to classify injuries to the upper limb due to tumble dryer trauma in children.

Injury	Score
Soft tissue trauma to the upper limb without bone injury	1
Upper limb segment fracture without displacement	2
Upper limb segment fracture with displacement	3
Fracture combining two different segments, or two different areas in the same segment (floating elbow) with at least one displacement	4
Exposed fracture	5
Compartment syndrome	6
Traumatic amputation of the upper limb	7

Classification
• TYPE I (Mild) Score <3 Outpatient management. • TYPE II (Moderate) Score 3 - 4 In-hospital stay 24 – 48 hs. Inadequate management may lead to long-term damage • TYPE III (Severe) Score 5 – 7 Extended in-hospital stay > 48 hs. Potential limb viability or function loss. Potential life-threatening injury.

Table 2. *Epidemiological data.*

N	Average age (years)	Gender		Follow up average years	Side		Classification		
		<i>M</i>	<i>F</i>		D	I	Type I	Type II	Type III
77	4	42	35	3,2	40	37	6	54	17

Table 3. 144 fractures in 77 patients.

Diaphyseal fractures humerus (N 54)	Elbow area (N 13)	Diaphyseal fractures forearm (N 63)	Wrist area (N10)	Exposed fractures (N 15)
(29) 12-D/5.2	(9) supracondylar fractures Gartlan III	(35) 22-D/5.1	(7) 23-M/3.1	(5) humerus only
(25)12-D/5.1	(4) external ulna	(18) 22-D/5.2	(2) 23r-M/3.1	(4) forearm only
		(6) 22-D/4.1	(1) 23-M/2.1	(6) both segments
		(2) 22-D/2.1		
		(1) 22u-D/2.1		
		(1) 22u-D/5.1		

Four patients presented diaphyseal humeral fractures in combination with elbow area fractures

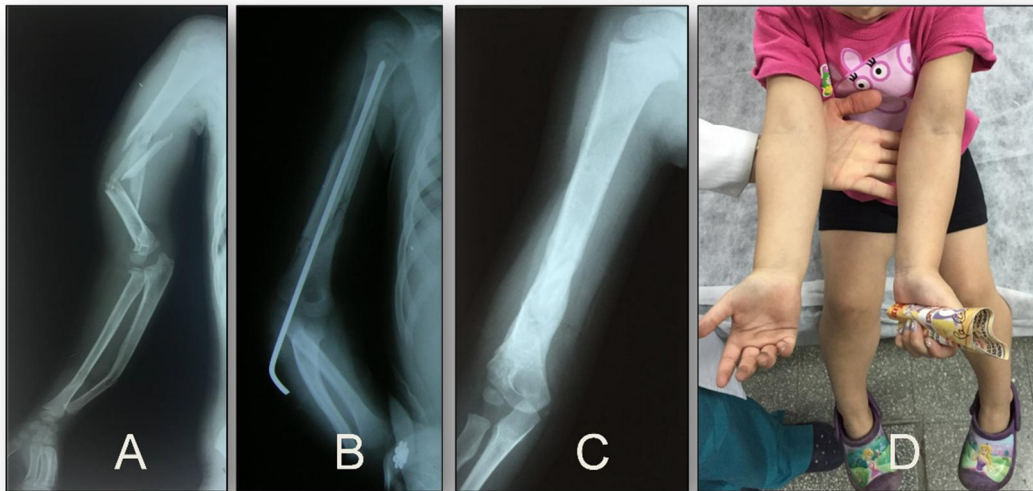


Figure 1. Female patient, 3 years old. A) diaphyseal humeral fracture 12- D/5.2. Diaphyseal ulnar fractures 22u-D/2.1. Score assigned: 4 points (floating elbow) Injury TYPE II. B) Taken to the OR, humeral fracture, closed reduction. Intramedullary retrograde nailing going through external condyle. Ulna: closed reduction. Immobilization method: velpau cast. XR follow up for 45 days post op without cast. C) XR 6 months post op, axial consolidation. D) Patient's clinical image 18 months aster surgery: good axis, full mobility, function completely restored.



Figure 2. Male patient, 4 years old. A) open diaphyseal humeral fracture 12-D/5.2. Gustilo II + external condyle fracture. Forearm presents a 22u-D/5 fracture. Surgical debridement and nailing performed. B) XR and P 7 months after surgery: diaphyseal pseudoarthrosis in the humerus.

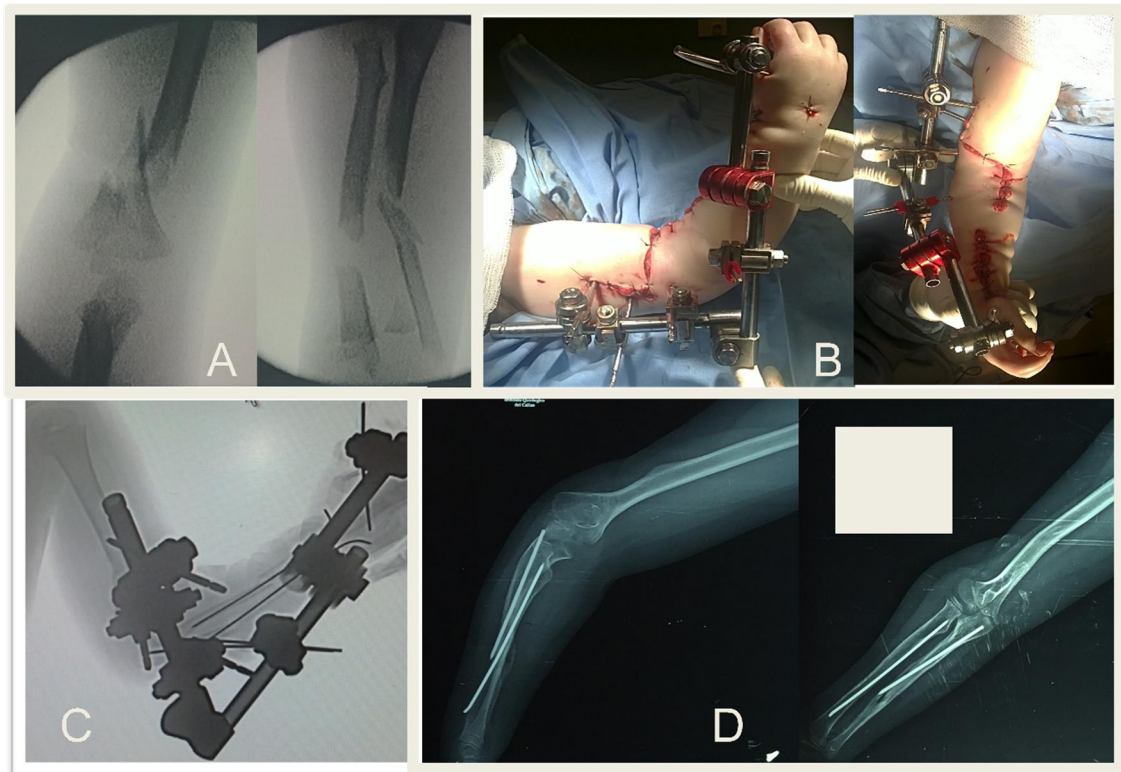


Figure 3. Male patient, 3 years old. A) Image from amplifier. Open humeral fracture 12-D/5.1. Gustilo II + open forearm fracture 22-D/5.2 Gustilo I. Exposed floating elbow. Score assigned: 5 points. Severe injury type III. B) Post op clinical image, toilette, preventive fasciotomy + external fixation and intramedullary nailing in the forearm. C) XR post op. D) XR 4 years after surgery. Good axis and excellent clinical function.

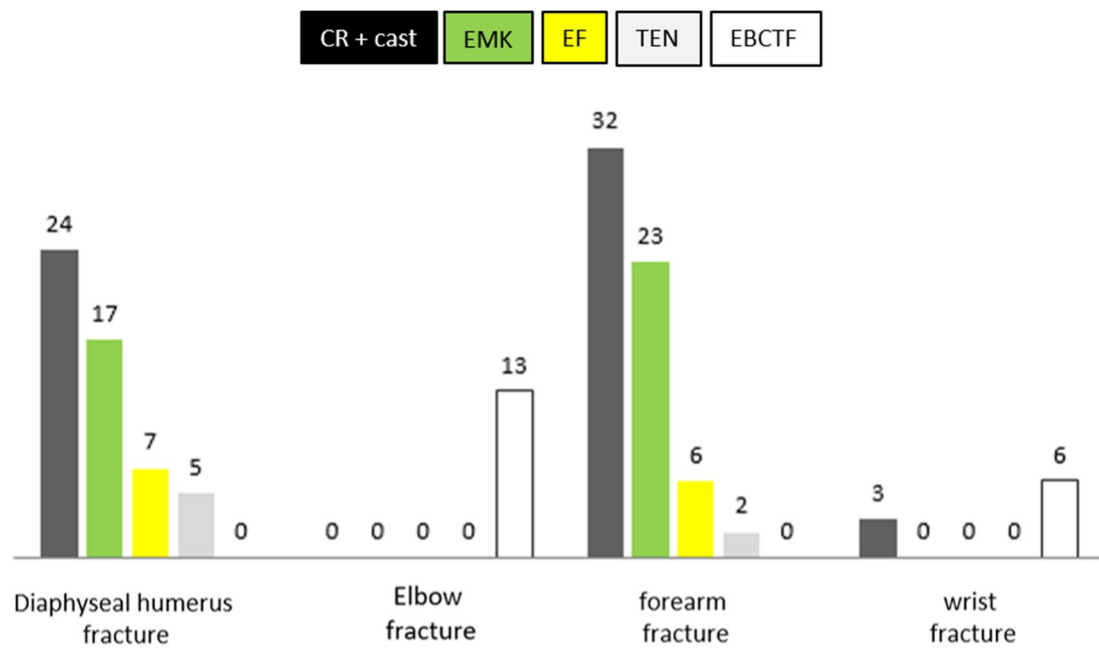


Figure 4: Stabilization/Fixation method

CR + cast: closed reduction; EMK: intramedullary fixation using Kirschner wires; EF: External Fixator; TEN: Titanium Elastic Nail; EBCTF: bicortical- transfocal fixation.

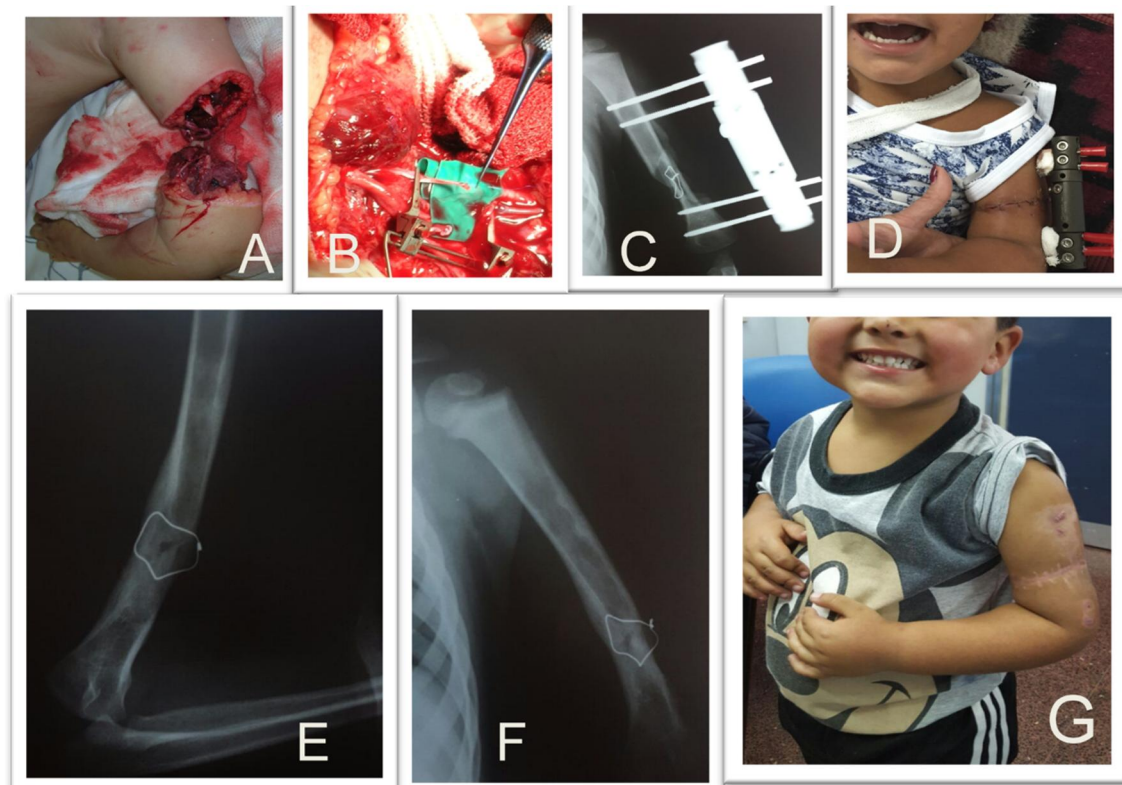


Figure 5. 3 year-old patient. A) Traumatic amputation of upper limb due to tumble dryer trauma. Score assigned: 7 severe injury Type III. B) Intraoperative image during reattachment. Vascular seams can be observed. C) and D) Post op images 30 days after surgery. The limb is viable and the fracture shows consolidation con external fixation. E) and F) XA 10 months after reattachment, consolidated fracture. G) Happy patient in recovery, showing active elbow flexion.

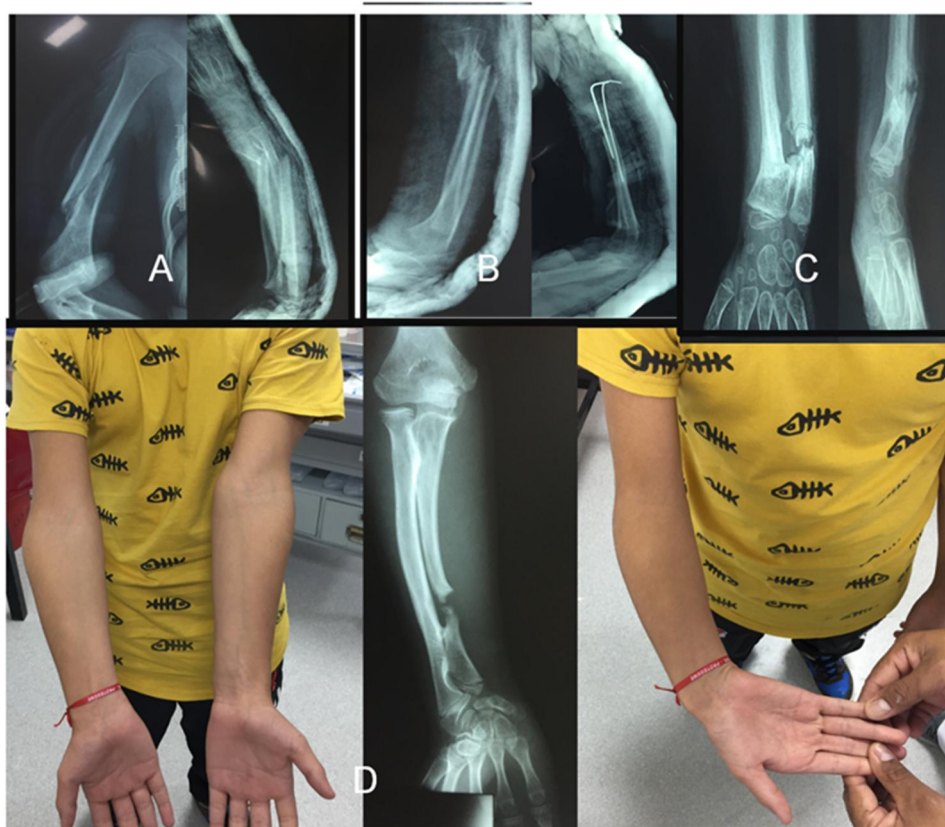


Figure 6. Male patient, 7 years old. Humeral fracture by tumble dryer 12-D/5.1 and wrist 23-M/3.1. Closed floating elbow. Score assigned: 4. Injury Type II. Bloddless treatment, reduction and cast. B) 35 dias after surgery there is evidence of malunion in fractured wrist. An open reduction and arthrodesis are

performed. C) % months after surgery, there is evidence of ulnar psedoarthrosis.

D) 4 years later, there is evidence of radioulnar synostosis with ulnar psedoarthrosis and ulnar deviation of the carpus. There is also evidence of varus elbow.

Figure 7: algorithm and therapeutic recommendations

