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The Rule of the Ring

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Orthopedics is often about pattern recognition.
What do these two fractures have in common?

Figure 1

Figure 2

They obey 'The Rule of the Ring."

The forearm and leg are tightly bound structures with ligamentous attachments at both ends and an interosseous membrane along most of their length to stabilize them and maintain their congruity during motion (Figure 3).

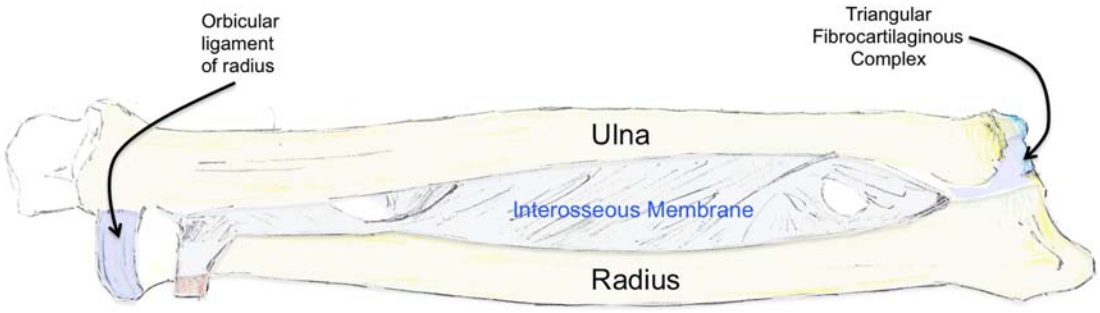

Figure 3

Acting as a unit makes it very hard to displace one of the bones without displacing the other. Hence, 'The Rule of the Ring' for the forearm or leg is:

One bone cannot be displaced without displacing the other.

This is the same as breaking the type of ring one wears (Figure 4).

Figure 4

One break in a ring does not make it fall off (unstable) but the second break does. As is the case for a ring so it is with the forearm and leg. One bony break does not make the entire unit unstable but two does. It is this instability that often leads to the problems of healing and complications of the fracture.

This rule is manifest in many forms but "The Rule of the Ring" theme allows a canny physician to discern the subtle variations.

Both bones fractures of either the forearm or the leg are fairly obvious. One can easily see how the forces were dissipated and the interosseous membrane damaged (Figure 5a,b) (Figure 6a,b).

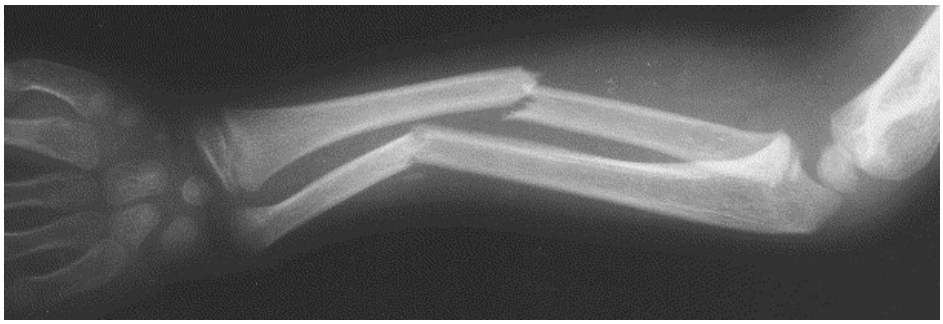

Figure 5a

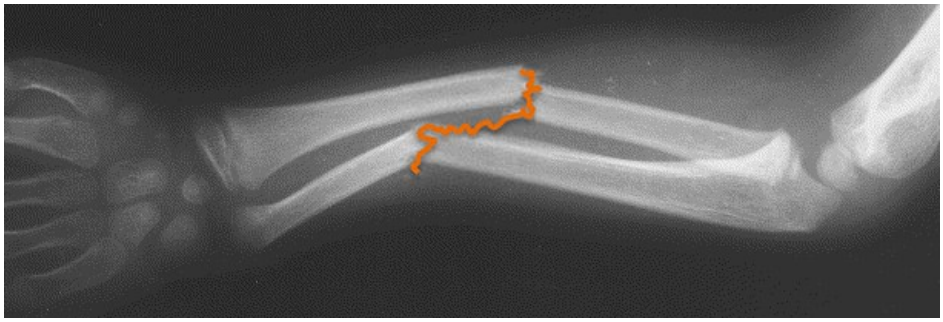

Figure 5b—Figure 5a with damaged structures including the interosseous membrane outlined in orange

Figure 6

Figure 6b—6a with damage in beige

It is common to have torus fractures of the distal radius in children but no ulnar involvement. It has been conjectured that the relatively thicker diaphyseal cortex is axially compressed into the thinner metaphyseal cortex causing microfractures and buckling the area (Figure 7a,b) (1).

Figure 7a

Figure 7b—7a with torus fracture in beige

This is much like compressing a disposable cup (Figure 8a,b) with the buckling showing the typical x-ray findings of a torus fracture.

Figure 8a

Figure 8b—axial force simulating torus fracture

Consequently, torus fractures are ***always metaphyseal injuries*** and only in ***young children*** (Young children are the only people with bones supple enough to respond to axial stress in this fashion) (Figure 9a,b).

Figure 9a

Figure 9b—9a with torus fracture in beige

Torus fractures frequently have only the radius (one bone) injured. Nevertheless, they do not break "The Rule of the Ring" because the fracture is not displaced and the stability of the ring is not compromised. There is not another displaced bone.

"The Rule of the Ring" seems a little metaphysical or at least like it is a term from Middle Earth. How does it help an emergency physician? It reminds the physician to look for part two of the injury. This second part may be obvious or subtle (Figure 10a,b).

Figure 10a Obvious tibia fracture

Figure 10b More subtle fibula component

Part two of the displacement may be dislocation of a nearby joint or of a distal fracture. It is this search for the second displacement that is the point of this discussion. Keeping in mind the two part nature of displaced injuries of the forearm and leg allows the canny physician to find the lurking subtle problems.

We now embark on an overview of more subtle two part injuries. With "The Rule of the Ring" to guide us, the idiosyncrasies of these injuries are now expected rather than mysterious.

Consider the injury shown in the x-rays below as a subtle injury that follows "The Rule of the Ring" (Figure 11a,b).

Figure 11a

Figure 11b

This is a **Maisonneuve's fracture.** It is a classic emergency physician "miss." There is an external rotation of the foot with medial malleolar area injury. The proximal fibular fracture could be easily overlooked if one did not seek part two of the injury by following our rule. The instability brought about by breaking the ring may result in poor patient outcomes if not discovered.

Most ankle injuries are inversion problems and there is lateral malleolar pain and tenderness to go with this. Maisonneuve injuries have medial malleolar damage either of the medial malleolus itself or of the deltoid ligament. The mechanism is not inversion, but rather the more unusual external rotation (2,3) (Figures 12 and 13).

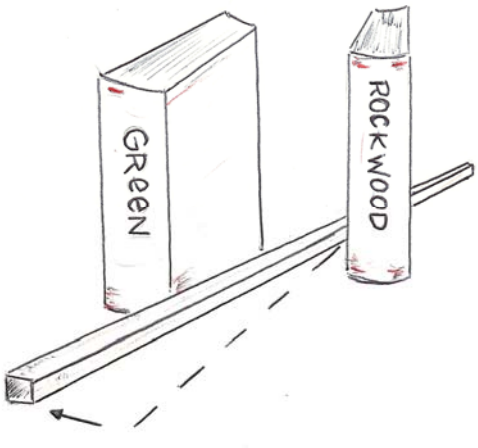

Figure 12

Figure 13

External rotation injures the medial malleolus, tears the distal tibiofibular ligaments (syndesmotic joint), rips up the interosseous membrane, and finally exits the fibula at some more proximal site. (Figure 14)

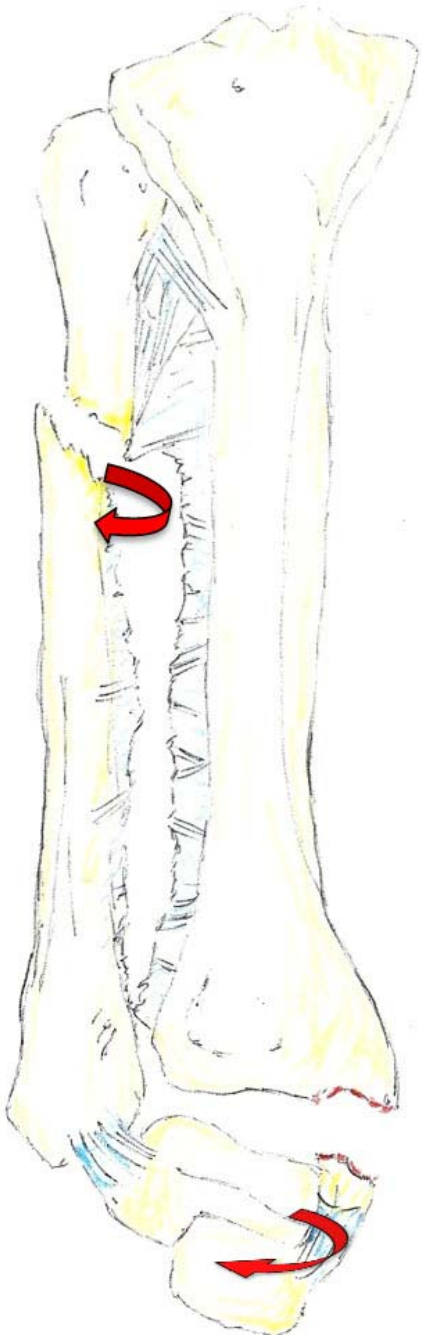

Figure 14

This general injury pattern has several eponyms depending on where the fibular fracture is located. Pott's fracture is fairly distal (Figure 15) and Maisonneuve's fracture more proximal (Figure 16). These injuries occur by the same mechanism and are associated with damage to the stabilizers of the lower leg: the interosseous membrane as well as the distal tibiofibular ligaments. The eponyms don't really matter to us - it is this pairing of bony injuries that is important.

Figure 15 Fracture of the distal fibula

Figure 16 Fracture of the proximal fibula

Thus, with the Maisonneuve injury we have a patient with an unusual mechanism of injury and medial malleolar pain. Distal fibular injuries are fairly easily detected by history and physical examination since the fibula is close to the skin distally. Proximal fractures are another animal entirely. They are sequestered beneath a fair amount of muscle and not visually obvious. (Figures 17a,b) Indeed, even ecchymosis from the fibular fracture may not be visible for several days.

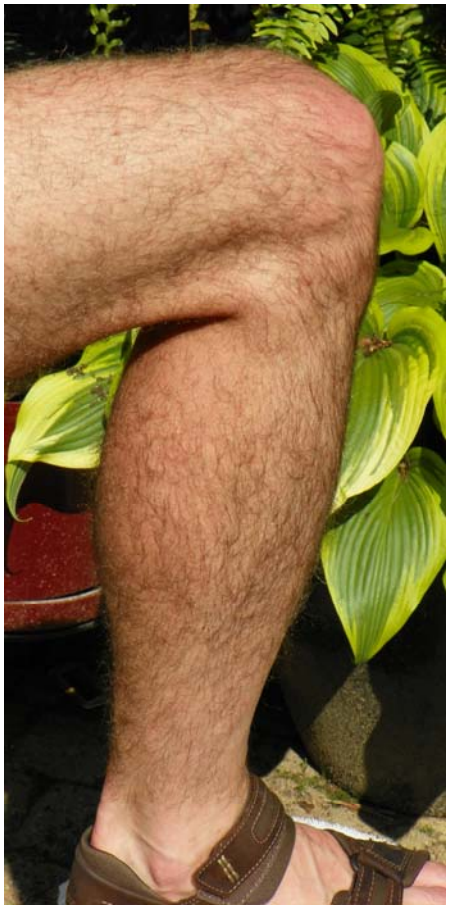

Figure 17a

Figure 17b—17a with proximal fibula outlined

These injuries are easy to miss because half of the damage is not readily apparent.

Clues to the true nature of the problem may be sleuthed from "The Rule of the Ring." Damage to the medial malleolar structures, most commonly the deltoid ligament, may lead to a widened medial clear space (Figure 18a,b).

Figure 18a

Figure 18b—18a with medial clear space in yellow

Hence, there is a displaced break in the ring and a second break must be present somewhere.

Additionally, a widening of the space between the distal tibia and fibula reveals damage to these ligaments. The implication is that there must be damage to the interosseous membrane (3,4) (Figure 19a,b,c).

Figure 19a

Figure 19b—wide space indicates damage to ligaments

Figure 19c—torn interosseous membrane

Thus, our attention is directed up the leg to the relatively hidden proximal fibular fracture (Figure 20 a,b).

Figure 20a

Figure 20b—20a showing proximal fibula fracture

This combination of injuries makes the leg unstable and surgery is usually required.

About 25% of the time the Maisonneuve injury is associated with a medial malleolus fracture instead of a deltoid ligament tear. The presence of this fracture should instigate further examination looking for displacement. Application of "The Rule of the Ring" ensures a search for the proximal fibular fracture. Do not be lulled into complacency by finding ***the*** fracture (Figure 21a - f).

Figure 21a

Figure 21b

Figure 21c

Figure 21d—21a fracture in beige

Figure 21e—21b arrow indicates fracture Figure 21f—21c fracture in beige

One additional clue to the proximal fracture might be paresthesias of the dorsal first web space or weakness extending the great toe. The proximal fibular fracture may damage the deep peroneal nerve which is closely approximated to the fibula just below its head (Figure 22).

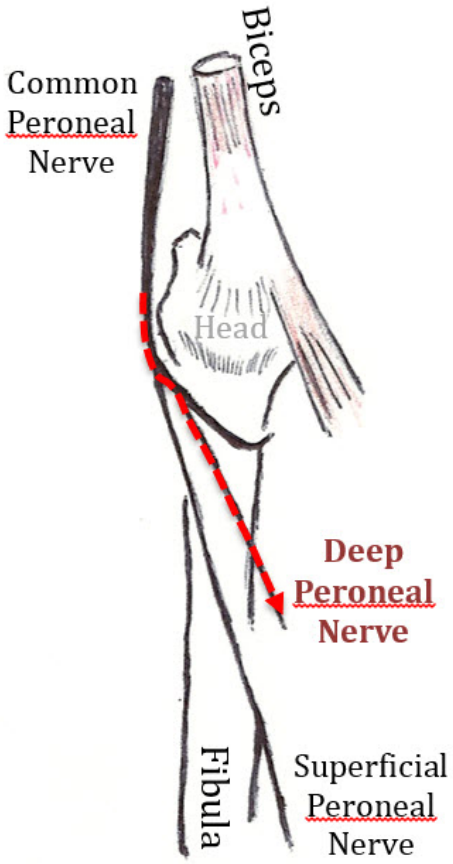

Figure 22—Deep peroneal nerve in dashed red

Damage to the deep peroneal nerve may cause weakness of great toe extension and will be given away by paresthesias in the first dorsal web space (Figure 23).

Figure 23—Sensory area of the deep peroneal nerve

Thus, our patient with the uncommon external foot rotation mechanism and medial malleolus injury should have "The Rule of the Ring" applied to discover a proximal fibula injury. Examination includes checking for paresthesias of the first dorsal web space.

Treatment of Maisonneuve Injury

Long leg immobilization and orthopedic consultation to arrange for definitive care is typical. Definitive care is almost always surgery (2-4).

Summary: Maisonneuve Fracture

- The medial malleolus, the distal tibiofibular ligament, the interosseous membrane, and the fibula are injured.
- It is caused by external rotation of the foot that is not the usual way an ankle is injured. There will be medial malleolus and proximal fibula tenderness.
- The fibula fracture is often too proximal to be seen on ankle x-rays.
- Medial malleolus damage is 75% of the time just deltoid ligament and 25% of the time a medial malleolus fracture.
- Long leg immobilization and refer for surgery

Figure 24 shows another injury in which application of "The Rule of the Ring" is helpful.

Figure 24

This injury obeys the rule of the ring but is somewhat subtle. There is an obviously displaced radius fracture but no readily apparent second displacement. The rule exhorts us to expect an injury of the ulna. Careful examination does reveal the expected injury. The ulnar injury is a

dislocation of the distal radioulnar joint (DRUJ). Figures 25a,b shows the normal distal radioulnar alignment on the right and a dislocation DRUJ on the left.

Figure 25a—dislocated DRUJ **Figure 25b—relocated DRU**

The case presented is **Galeazzi's fracture**. It consists of a distal radius fracture with disruption of the distal radioulnar joint. Though Galeazzi's fracture is the most common of the subtle fracture-dislocations of the forearm, it accounts for just a small portion of all forearm fractures (5). Nevertheless, emergency physicians should expect to see this injury occasionally over the course of their career.

The interosseous membrane which stabilizes the radius and ulna does not attach from the distal 1/3 of the radius to the distal ¼ of the ulna. Consequently, fractures of the radius in this area are more unstable than those in more proximal locations. Compounding this problem is attachment of the bracheoradialis and pronator quadratus to the distal radius. Each muscle tends to displace an unstabilized fragment and confounds attempts to maintain a closed reduction (5-7) (Figure 26).

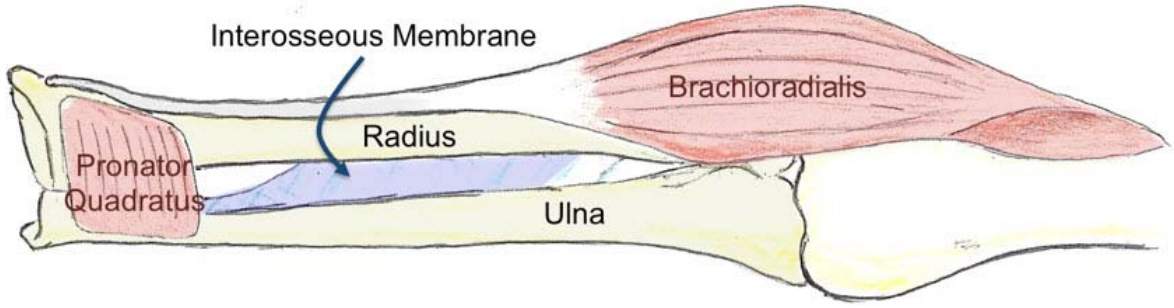

Figure 26

The usual mechanism of injury is a fall on the outstretched hand (FOSH) in either full pronation or supination.

Physical examination reveals an obvious radius fracture. Galeazzi fractures usually do not occur less than 5 cm from the distal radioulnar joint but are most common within 7.5 cm (2-3 inches). It is the diagnostic "sweet spot." Careful evaluation will also demonstrate DRUJ tenderness and usually displacement of the ulnar head. Fortunately, neurovascular problems are unusual.

Imaging of Galeazzi's fracture demonstrates shortening, displacement or angulation of the distal radius with misalignment of the DRUJ (Figures 27a,b).

Figure27a **Figure 27b**

Often this misalignment is best seen in the lateral view. (Figures 28 a,b,c and Figures 29 a,b,c,d)

Figure 28 a,b—Obvious radius fracture

Figure 28c—subtle dislocation of the DRUJ indicated with arrow

Figure 29 a—widening of DRUJ

Figure 29b

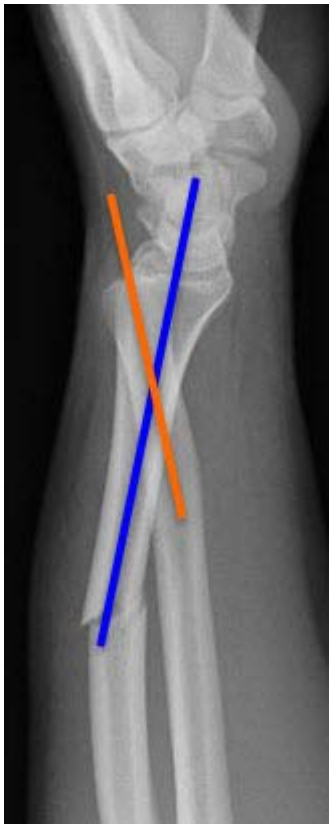

Figure 29c—nonalignment of radius and ulna demonstrated with lines.

Thoughtful attention should be paid to the DRUJ when there is a distal radius fracture. The powerful and stabilizing triangular fibrocartilaginous complex attaches the distal radius to the ulnar styloid (8) (Figure 30).

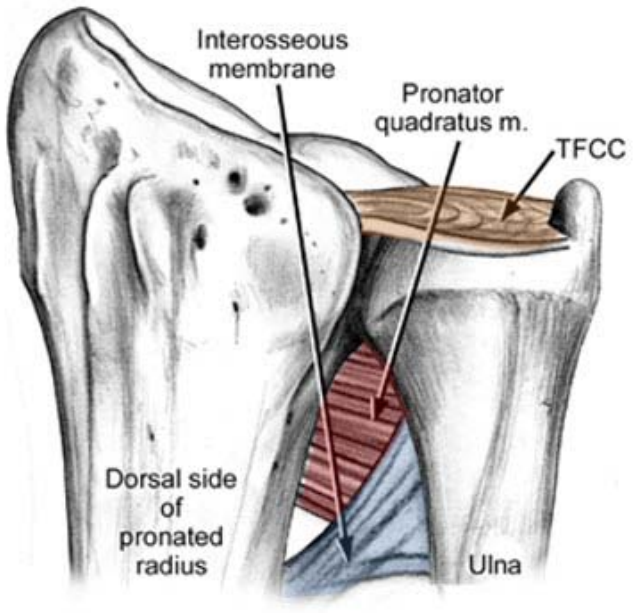

Figure 30

A fracture of the ulnar styloid process or nonalignment of the distal radius and ulna are suggestive of minimally displaced Galeazzi fractures.

Mikic demonstrated 20% of patients with Galeazzi's fracture had a normal appearance of the DRUJ on x-rays despite an ulnar head disruption (9). (Everything seems to have its exception.) In such cases, the diagnosis must be made on clinical grounds based upon tenderness of the DRUJ and the characteristic distal radius fracture.

Galeazzi's Fracture Treatment

Galeazzi's fracture has been termed the "fracture of necessity" since surgery is required to avoid the almost universal poor outcomes of conservative treatment. Emergency department treatment consists of long arm immobilization and referral to orthopedics for surgical stabilization (10-14).

In contradistinction to adults, children with Galeazzi's fracture often do not require surgery and heal well with immobilization if the radius is reduced. Initial emergency department treatment is the same as in adults with perhaps different predictions of what will happen (15).

Summary of Galeazzi's Fracture

- Fracture of the distal radius with disruption of the DRUJ.
- Mechanism
  - Fall on the outstretched hand
- Physical examination
  - Deformity of the radius
  - Tenderness over the DRUJ with possible deformity
- Treatment is surgical in adults.

Another classic application of the "Rule of the Ring" is shown in Figure 31.

Figure 31

There is an obviously displaced ulnar fracture. "The Rule of the Ring" predicts displacement of the radius. And, in fact, careful examination reveals a dislocation of the proximal radius from the capitellum of the humerus. This injury, fracture of the proximal ulna and dislocation of the radial head is **Monteggia's fracture.** It is the mirror image of Galeazzi's injury. The fracture switches bone, as does the dislocation. This mirroring makes this fracture-dislocation all the more obvious to a knowledgeable practitioner.

There are several injury mechanisms that may result in Monteggia's injury (16). They include:

1) FOSH in hyperpronation
2) Hyperextension of the elbow in children
3) A direct blow to the ulna

Classification of Monteggia's Injury

The dislocation may be in any direction and there are several classification systems for these combinations that are unimportant to emergency physicians. In fact, Bado began calling these Monteggia injuries in 1962 with his (at the time) new classification system (17). This system was modified over the years to include many variant lesions and classification systems. Some of these variants do not even include dislocations of the radiocapitellum joint. This accretion of variant injuries has helped to make the analysis of Monteggia's injury difficult in many respects. Treatment and outcomes for the broadening variations are quite different than those originally described by Bado and poorly correspond to clinical outcomes. Thus, the classification systems are of very little value to emergency physicians (18). *The crucial thing for an emergency physician to notice is that there are two parts of the injury and not recognizing both can lead to chronic disability for the patient.*

Imaging of Monteggia's Injury

One of the classic x-ray teachings about elbows comes from this injury: the proximal radius should articulate with the capitellum in every view (19). A line drawn through the distal radial neck perpendicular to the articular surface should intersect the capitellum **in every view**. Please note that the long axis of the radius is at about a 15 degree angle with the neck making a line drawn the radial neck the only accurate way to use this radiological sign. Some examples will make this clear (Figures 32a,b, 33, 34a,b).

Figure 32a

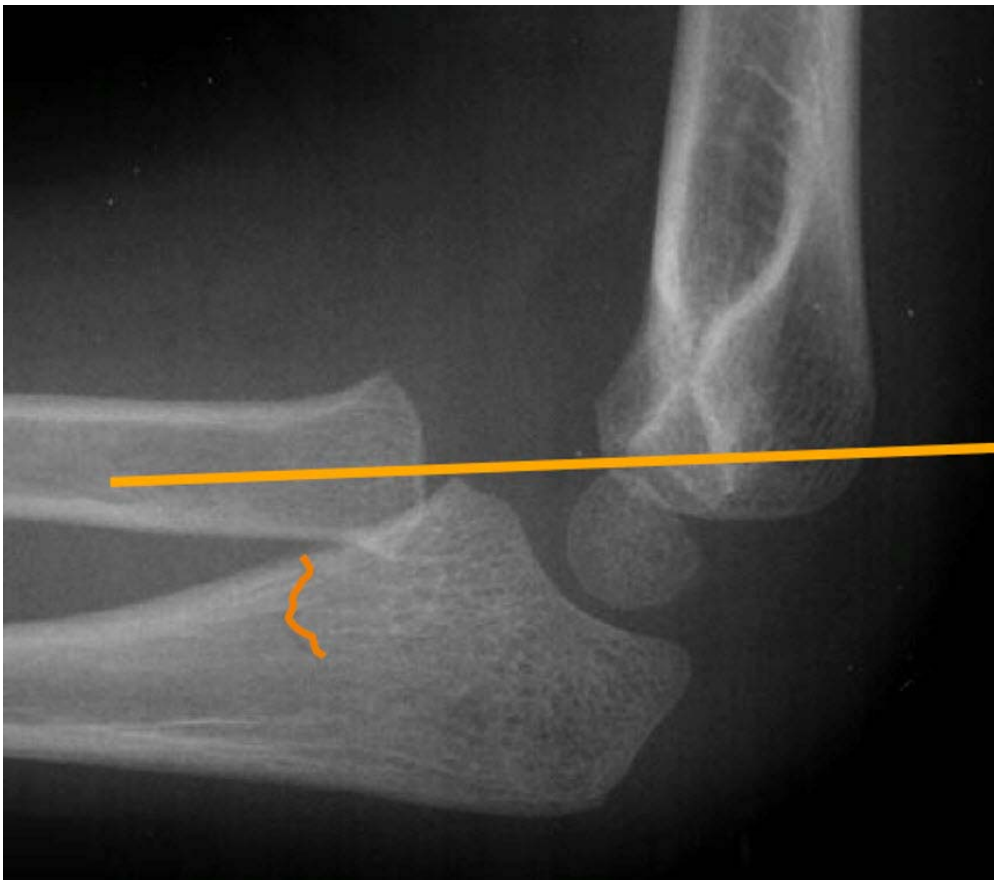

Figure 32b—Line drawn down the neck of the radius does not intersect the capitellum. Fracture of the ulna drawn in darker orange.

Figure 33—Clear example of fracture of the ulna and displaced radial head

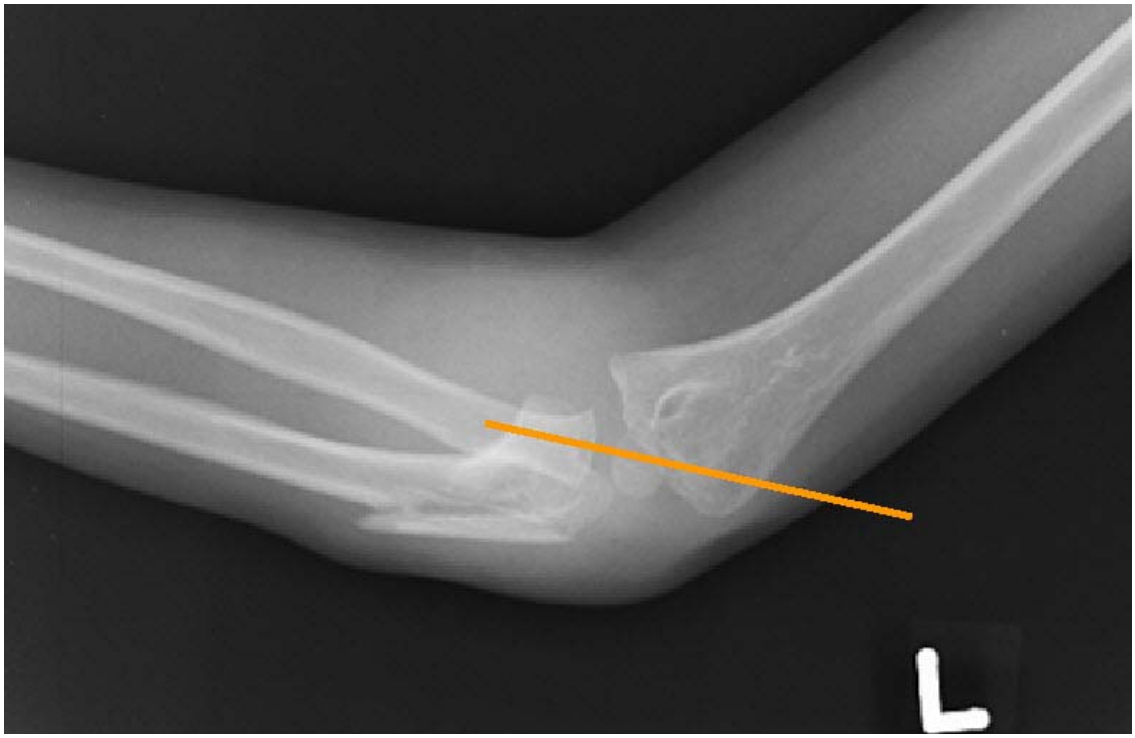

Figure 34a—In this view the line intersects the capitellum

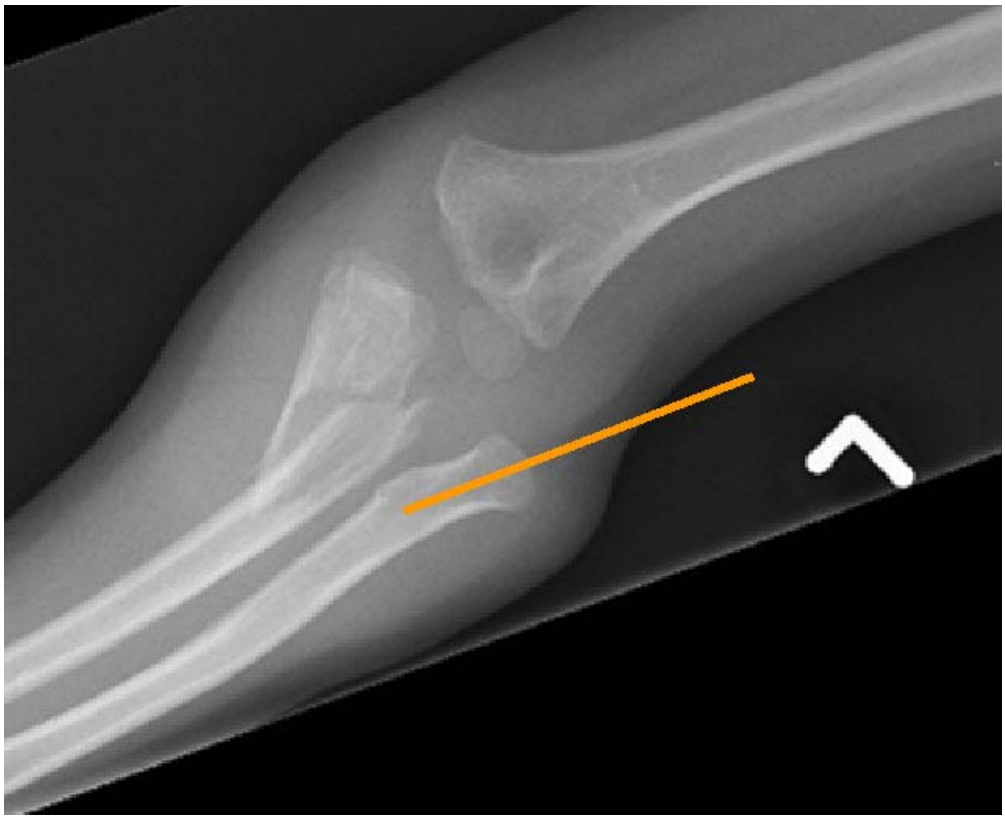

Figure 34b—But in this view the dislocation is quite obvious

To reiterate: **The radius should articulate with the capitellum in every view.**

Intuition would suggest that the direction of the radial head dislocation is in the same direction as the displacement of the ulna. This is, in fact, true (Figure 35).

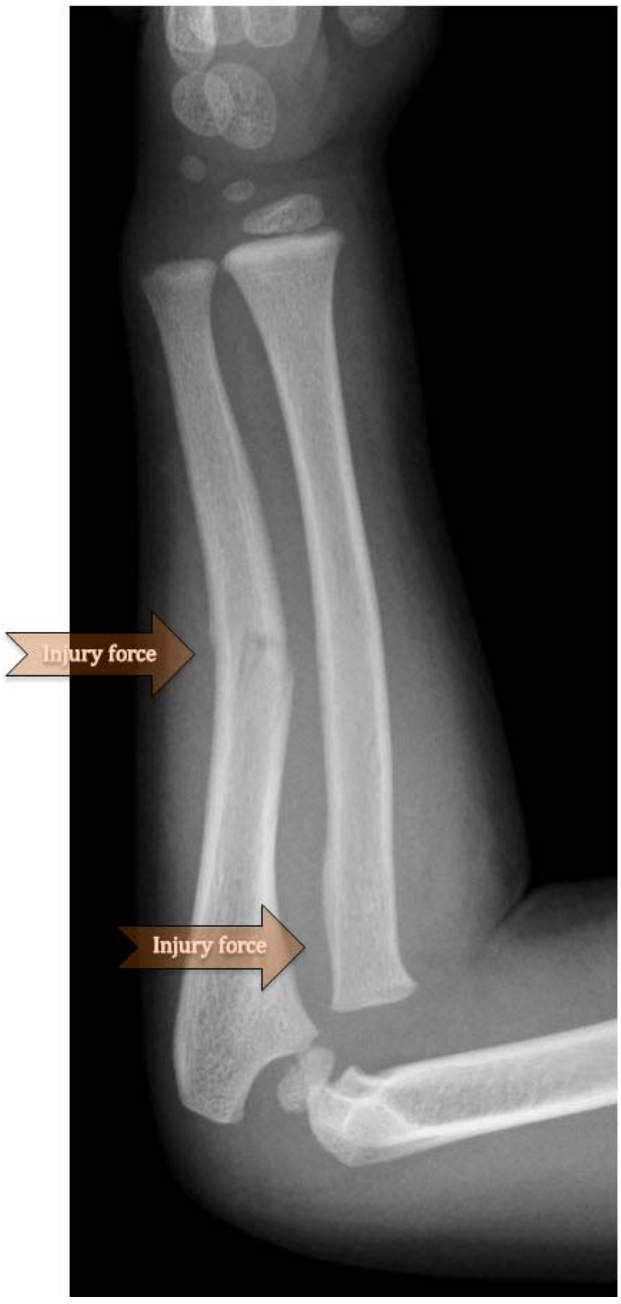

Figure 35—Injury force applied to the ulna has the same direction as the radial head dislocation.

Plastic deformation fracture can make recognition of this injury especially difficult in young children (20) (Figure 36a,b).

Plastic deformation consists of numerous microfractures in pliable young bone deforming the ulna which accompanies the radial head dislocation. "The Rule of the Ring" is employed to discover the plastic deformation of the ulna when the dislocated radial head is noticed. (Plastic deformation fractures are elaborated upon later in this article). The lack of an

apparent and expected ulnar fracture should be the tip-off of this very subtle injury.

Figure 36a

Figure 36b—Figure 36a with orange line demonstrating radial head not articulating with the capitellum and yellow line demonstrating the ulnar border's deviation from straight.

Complications of Monteggia's Injury

Complications of Monteggia's injury include a higher than usual nonunion rate, elbow stiffness, and stretching injuries of the radial nerve branches. Most commonly the posterior interosseous nerve is injured. Fortunately, the natural history of these nerve stretchings or contusions is spontaneous recovery over 6-12 weeks (16).

Treatment of Monteggia's Fracture-Dislocation

There are significant differences in the outcome and treatment of this injury between children and adults. Adults commonly have posterior dislocations of the radial head. In fact, in many series this is the predominant form of dislocation. These posterior dislocations frequently have radial head or coronoid process fractures which contribute to much poorer patient outcomes. Open reduction and internal fixation of the injury is the usual treatment in adults. Referring to the treatment outcomes of Monteggia's fracture in 1955, Watson-Jones said: "no treatment is characterized by such general failure." Operative results are now impressively better than in 1955. Nevertheless, it is quite common to have only fair or even poor results when treating this injury (21-23).

Children, on the other hand, most commonly have anterior dislocations. In fact, almost uniformly good outcomes result for children regardless of the type of Monteggia injury (16,19). Only a tiny minority will require an open reduction. It is important for us to apply the "The Rule of the Ring," discover the problem, and properly refer the patients to an orthopedic surgeon or hand specialist.

Summary of Monteggia's Fracture

- A displaced proximal ulna fracture is often associated with a radial head dislocation.

- A line drawn down the radial neck perpendicular to the joint surface should intersect the capitellum in every view.
- Follow up with orthopedics is important for these injuries. Adults usually require surgery while children almost never do.

The third of the subtle fracture-dislocations of the forearm is the Essex-Lopresti injury. It consists of a fracture of the proximal radius, radius shortening, disruption of the distal radial ulnar joint, and a tear of the interosseous membrane. This is caused by a high energy FOSH injury. An example of this would be falling from a ladder on the outstretched hand. Severe comminution of the radial head is common as seen in Figure 37.

Figure 37

The radial head displacement with its attendant radius shortening and "The Rule of the Ring" predicts the ulna to be damaged. There is disruption of the distal radioulnar joint and of the stabilizing interosseous membrane (24) (Figures 38a,b and 39).

Figure 38a **Figure 38b—38a with arrow showing displacement of ulna**

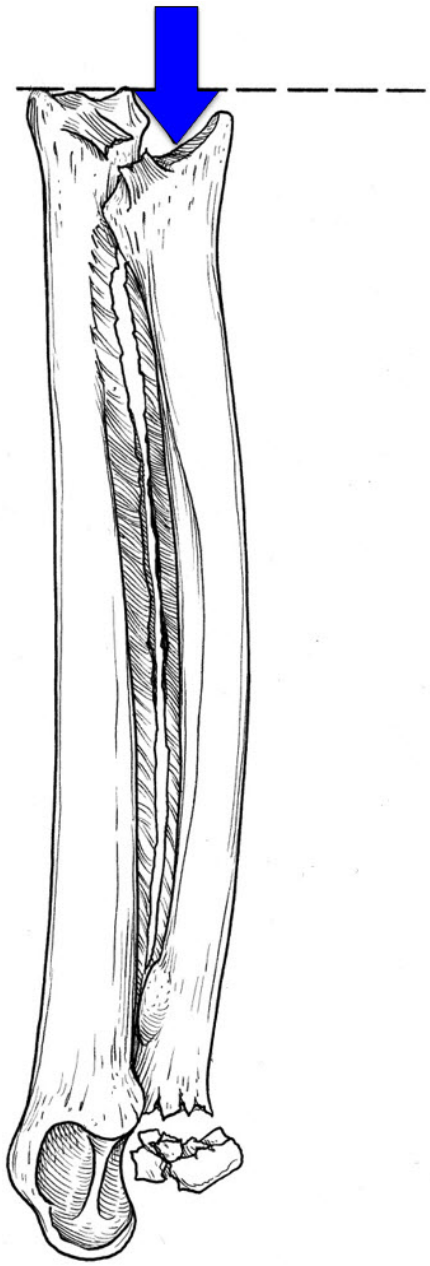

Figure 39

Physical Examination

Typically, the examiner's attention is drawn to the painful and radiologically obvious elbow problem. Interestingly, the distal aspects of the injury are often not obvious to the examiner (24). Yet, the shortening of the radius prompts the canny physician to examine the remainder of the forearm and wrist looking for the second part of the injury. There may be forearm or wrist tenderness or even clear deformity of the distal ulna. Diffuse forearm pain and tenderness is from the interosseous membrane damage and is unusual with an isolated radial head fracture. This forearm tenderness should raise the possibility of the Essex-Lopresti injury. Ecchymosis often develops in the forearm but this takes time and most patients with this painful injury present early and before ecchymosis is present.

Imaging the Essex-Lopresti Injury

It is important to x-ray both joints of the forearm as well as its length. In fact, x-rays centered on the forearm may not show the subtle deformity of the DRUJ that a film centered on the wrist will. (Figures 40a-d)

Figure 40a—radial head smash

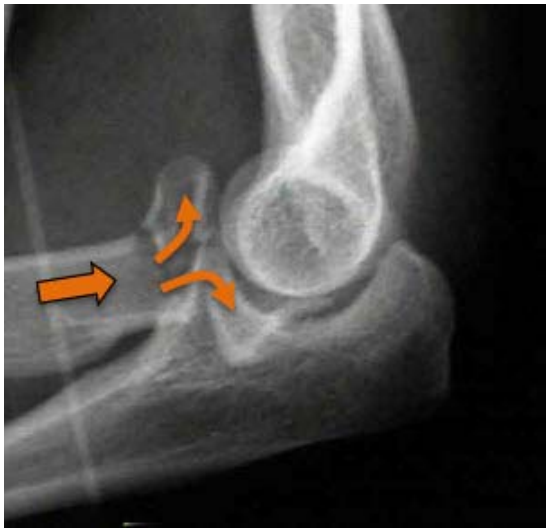

Figure 40b—40a with force and effect demonstrated

Figure 40c

Figure 40d—40c with force and effect shown

Treatment of Essex-Lopresti Injury

Treatment for acute Essex-Lopresti injuries is surgical with maintenance of the length of the radius paramount. Treatment of chronic injuries is much more difficult than acute injuries.

Early diagnosis results in the best possible outcomes for patients with this difficult but uncommon injury (25-29).

Summary: Essex-Lopresti Fracture

- High-energy mechanisms of injury are typical.
- A comminuted fracture or dislocation of the radial head, as well as forearm and/or wrist pain should alert the emergency physician to the possibility of this injury. Long arm immobilization and referral to orthopedic surgeon for definitive care is indicated.

A middle age patient was caught in a melee with police. Figure 41 reveals his injury. What is the problem?

Figure 41

This is a **Nightstick Fracture**.

It sort of looks like Galeazzi's injury but the distal ulna is fractured not the radius.
Of course, every rule has an exception and so does "The Rule of the Ring." A nightstick fracture is an isolated fracture of the ulna with no joint or radius involvement. It is caused by a direct blow rather than a fall. It was originally named after injuries incurred while police were dispersing crowds with billy clubs. (Figure 42)

Figure 42

The patient blocks the club's blow with the forearm exposing the ulna to the brunt of the injury. Figure 43a,b shows another example of the Nightstick Fracture.

Figure 43a **Figure 43b**

The ulna may be displaced but the radius and interosseous membrane are not significantly damaged. Consequently, the fracture is stable and may or may not need surgical treatment.

Emergency department treatment is long arm immobilization and referral to orthopedic surgery (30-32).

You might surmise that an equivalent direct blow to the fibula might result in an undisplaced fracture and you would be right. (Figure 44)

Figure 44

Isolated fibular injuries do occur but are less common than the nightstick fracture because the mechanism of injury is not as common in the lower extremity. Just like their upper extremity compatriots, they require long leg immobilization and referral to an orthopedic surgeon.

Isolated radius fractures without a second displacement may also occur as in Figure 45. This figure shows the radius of a child struck by a golf club when standing too close to the swinger. Isolated radius fractures are far more unusual than the ulna because the usual nightstick mechanism of protection is missing. In addition, the radius is considerably better protected by soft tissues than the ulna.

Figure 45

The results of treatment of an isolated radius fracture should be better than that of the more complex two-part injuries. The important point is that the "The Rule of the Ring" should be considered in all displaced forearm fractures (33,34).

We will end this article with an unusual application of "The Rule of the Ring" as seen in Figure 46a,b.

Figure 46a

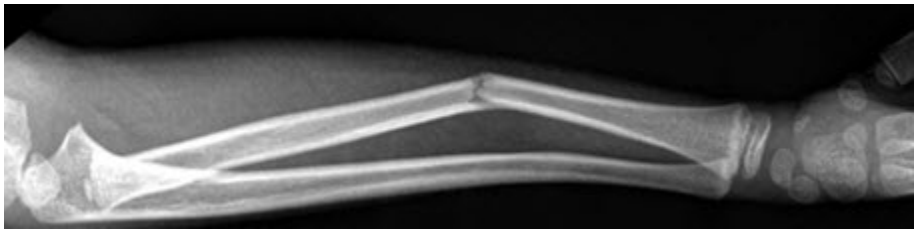

Figure 46b

We have a child with a displaced fracture of the radius and no obvious other injury. "The Rule of the Ring" implies there should be an injury of the ulna. There is: a plastic deformation fracture.

Mechanism of Plastic Deformation Fractures

Young bone when compressed begins the breaking process with microfractures of the cortex that eventually extend deeper and traverse the entire bone. If the compression force is removed before the microfractures extend to a critical depth, a deformity of the bone without an overt cortical break will result. This bowing deformity will not return to its prestressed alignment. This is plastic deformation (35,36). As may be imagined, this only occurs in the pliable bones of children. *Adults never have this injury.*

Acute plastic deformation fracture (APDF) is most common in the forearm but may also occur in the leg. The relatively rare APDF may include any combination of overt fracture of the radius with APDF of the ulna, fracture of the ulna with APDF of the radius, or APDF of both bones simultaneously. Nevertheless, the ulna is the more commonly involved of the two bones.

Lack of a cortical defect and subtle curvature of the long bone makes discovery of this injury difficult (35). Nevertheless, as "The Rule of the Ring" suggests, when there is a displaced fracture of one bone in the forearm, the physician should be looking for its partner. APDF may be the "partner" to an otherwise obviously displaced fracture in the forearm (Figure 47a,b).

Figure 47a **Figure 47b—47a with deformity in beige**

There is, of course, the equivalent injury in the leg of young children as shown in Figure 48a,b.

Figure 48a

Figure 48b—48a with deformity in beige

Good AP and lateral x-rays aid in discovery of this injury. If there is doubt about how the films should be interpreted, comparison views of the opposite extremity may be helpful.

Complications of this injury are well known. Natural remodeling may not be adequate to correct the deformity in older children. Bowing of a forearm bone causes abnormalities of the interosseous space that leads to problems pronating and supinating the forearm and its consequent poorer patient outcomes. Reduction of the obvious fracture may not be possible without reducing the plastic deformation.

Treatment of Plastic Deformation Fractures

Treatment often includes reduction under anesthesia by the orthopedic surgeon (36). Initial emergency department treatment is long arm/leg immobilization and prompt follow-up with the orthopedist.

Greenstick fractures represent the commonly occurring middle ground between complete bony fracture and plastic deformation of the bone. One cortex is overtly fractured but the other is plastically deformed. (Figures 49 and 50) Hence, greenstick fractures only occur in the supple bones of children.

Figure 49—Greenstick fracture white arrow. Torus fracture gray arrowhead.

Figure 50—Greenstick fractures both bones

Reduction of a greenstick fracture may be necessary when angulation is more than 15 degrees. They are initially treated with immobilization in a long-arm splint. Referral to orthopedic surgery is often appropriate.

Summary

When one bone in the leg or forearm is displaced there must be a second displacement in the other bone.

One bone cannot be displaced without displacing the other.

This "Rule of the Ring" is an important concept for emergency physicians. Expecting the second part of the injury allows one to seek out and find it even when it is subtle.

The subtle combinations are:
Maisonneuve fracture

Medial malleolus ligamentous injury with a proximal fibula fracture. Damage to the deep peroneal nerve is the possible complication.

Galeazzi fracture

Displaced distal radius fracture with dislocation of the distal radioulnar joint.

Monteggia fracture

Displaced proximal ulna fracture with dislocation of the proximal radioulnar joint.

Essex-Lopresti fracture

Fracture dislocation of the radial head with dislocation of the distal radioulnar joint. (The interosseous membrane is torn.)

All these injuries require long leg or long arm immobilization as well as referral to an orthopedic surgeon. Surgery is often required for best results.

May the rule be with you.

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