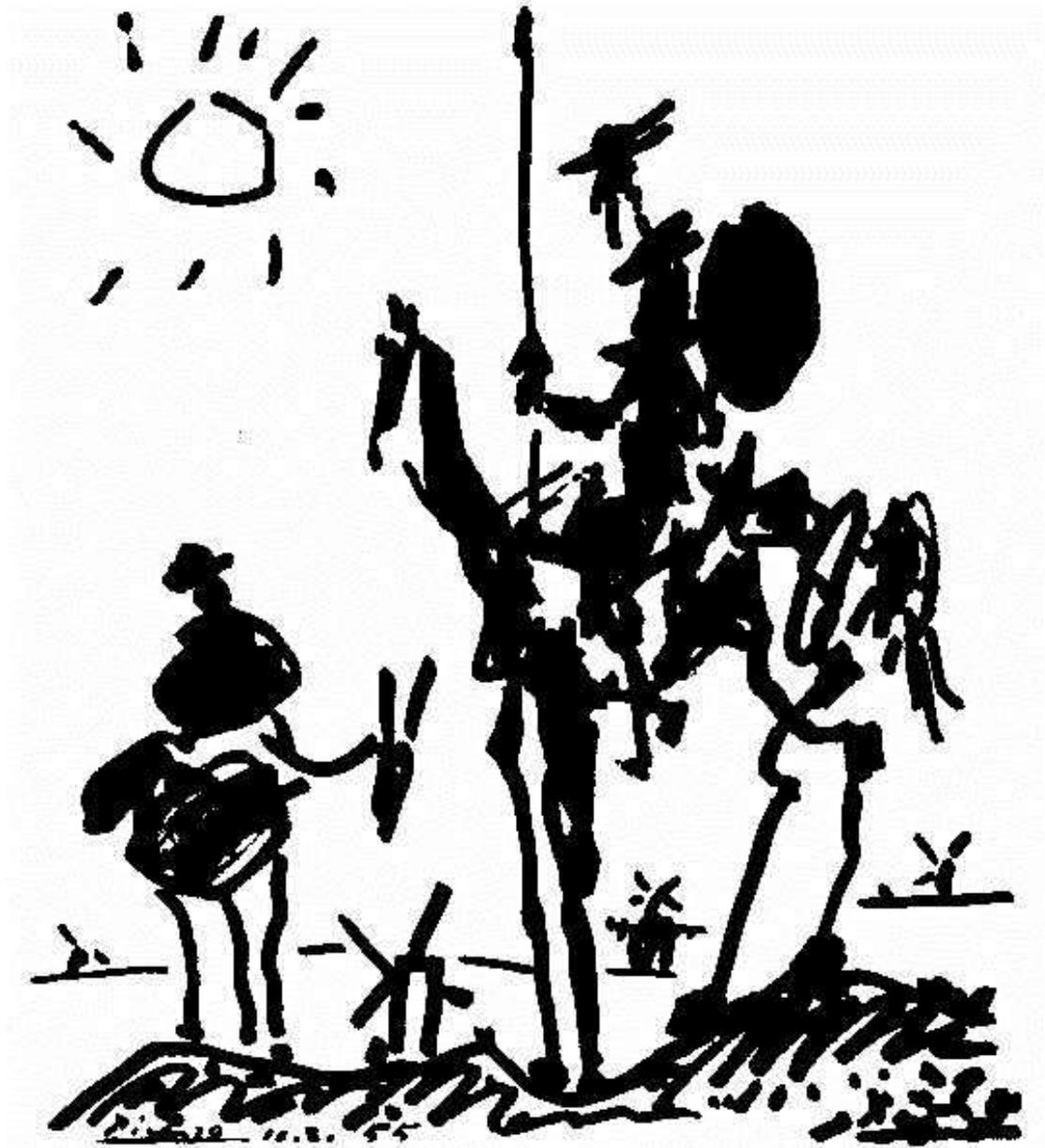


CHEST INJURY FLAIL SEGMENT



Don Quixote and Sancho Panza, ink on paper, Pablo Picasso, 1955, August 18-24 issue, Les Lettres Françaises.

...Regarding the good fortune of the valorous Don Quixote in the fearful and never imagined adventure of the windmills, along with other events worthy of joyful remembrance...

As they were talking they saw thirty or forty of the windmills found in that countryside, and as soon as Don Quixote caught sight of them, he said this to his squire;

“Good fortune is guiding our affairs better than we could have desired, for there you see, friend Sancho Panza thirty or more enormous giants with whom I intend to do battle, and whose lives I intend to take, and with the spoils we shall begin to grow rich, for this is righteous warfare, and it is a great service to God to remove so evil a breed from the face of the Earth”.

“What giants?”, said Sancho Panza.

“Those you see over there”, replied his master, “with the long arms; sometimes they are almost two leagues long!”.

“Look your grace”, Sancho responded, “those things that appear over there aren’t giants but windmills, and what looks like their arms are the sails that are turned by the wind and make the grindstone move”.

“It seems clear to me,” replied Don Quixote, “that thou art not well-versed in the matter of adventures: these are giants, and if thou art afraid, move aside and start to pray whilst I enter with them in fierce and unequal combat”.

And having said this, he spurred his horse, Rocinante, paying no attention to the shouts of his squire, Sancho, who warned him that, beyond any doubt, those things he was about to attack were windmills and not giants. But he was so convinced they were giants that he did not hear the shouts of his squire, Sancho, and could not see, though he was very close, what they really were; instead, he charged and called out:

“Flee not, cowards and base creatures, for it is a single knight who attacks you”.

Just then a gust of wind began to blow and the great sails began to move, seeing this, Don Quixote said:

“Even if you move more arms than the giant Briareus, you will answer to me”.

And saying this, and commending himself with all his heart to his lady Dulcinea, asking that she come to his aid at this critical moment, and well protected by his shield, with his lance in his socket, he charged at Rocinante’s full gallop and attacked the first mill he came to; and as he thrust his lance into the sail, the wind moved it with so much force that it broke the lance into pieces and picked up the horse and the knight, who then dropped to the ground and were very badly battered. Sancho Panza hurried to help as fast as his donkey could carry him, and when he reached them he discovered that Don Quixote could not move because he had taken so hard a fall with Rocinante.

“God save me!”, said Sancho. “Didn’t I tell your grace to watch what you were doing, that these were nothing but windmills, and only somebody whose head was full of them wouldn’t know that?”

“Be quiet, Sancho my friend,” replied Don Quixote. “Matters of war, more than any others, are subject to continual change, moreover, I think, and therefore it is true, that the same Freston the Wise who stole my room and my books has turned these giants into

windmills in order to deprive me of the glory of defeating them: such is the enmity he feels for me; but in the end his evil arts will not prevail against the power of my virtuous sword"...I remember reading that a Spanish knight named Diego Perez de Vargas, whose sword broke in battle, tore a heavy bough or branch from an oak tree and with it did such great deeds that day and thrashed so many Moors, that he was called Machuca, the Bruiser, and from that day forward he and his descendents were named Vargas y Machuca. I have told you this because from the fist oak that presents itself to me I intend to tear off another branch as good as the one I have in mind, and with it I shall do such great deeds that you will consider yourself fortunate for deserving to see them and for being a witness to things that can hardly be believed"

"It's in God's hands", said Sancho. "I believe everything your grace says, but sit a little straighter, it looks like your tilting, it must be from the battering you took when you fell"

"That's true," replied Don Quixote, "and if I do not complain about the pain, it is because it is not the custom of knights errant to complain about any wound, even if their innards are spilling out because of it".

"If that's true I have nothing to say," Sancho responded, "but God knows I'd be happy if your grace complained when something hurt you. As for me, I can say that I'll complain about the smallest pain I have, unless what you said about not complaining also applies to the squires of knights errant".

Don Quixote could not help laughing at his squire's simple mindedness, and so he declared that that he could certainly complain however and whenever he wanted, with or without cause, for as yet he had not read anything to the contrary in the order of chivalry. Sancho said that it was time to eat.

Miguel de Cervantes, *Don Quixote*, 1605-1615.

Like matters of war, theories of medicine are also subject to continual change! In the past the conventional wisdom was that the "pendeluft" phenomenon was the major contributor to hypoxia in cases of flail segment of the chest wall. As a consequence "strapping" the chest wall was considered first line treatment for these injuries. This was however fighting a chimera. As the great knight errant Don Quixote fought a chimera in the form of a windmill, so did we treat flail segments with "strapping". Flail segments are usually quite obvious on examination, however, with severe pain also comes severe splinting on the part of the patient, and just as the faithful Sancho Panza, noticed his uncomplaining master was somewhat tilting on his horse, all we may notice in a valiant uncomplaining patient may be a slight asymmetry in chest wall movement instead of the classically described "paradoxical movements". The valiant Don Quixote could well have suffered a flail segment in his mighty battle with the "giant", but as it is "not the custom of knights errant to complain about any wound, even if their innards are spilling out because of it", his faithful squire would greatly underestimate the severity of his master's injury. We must always consider the degree of pain a patient may be in with a flail segment, as it is the adequate treatment of pain which together with adequate oxygenation and ventilation which forms the cornerstones of treatment of flail segments of the chest wall.

CHEST INJURY FLAIL SEGMENT

Introduction

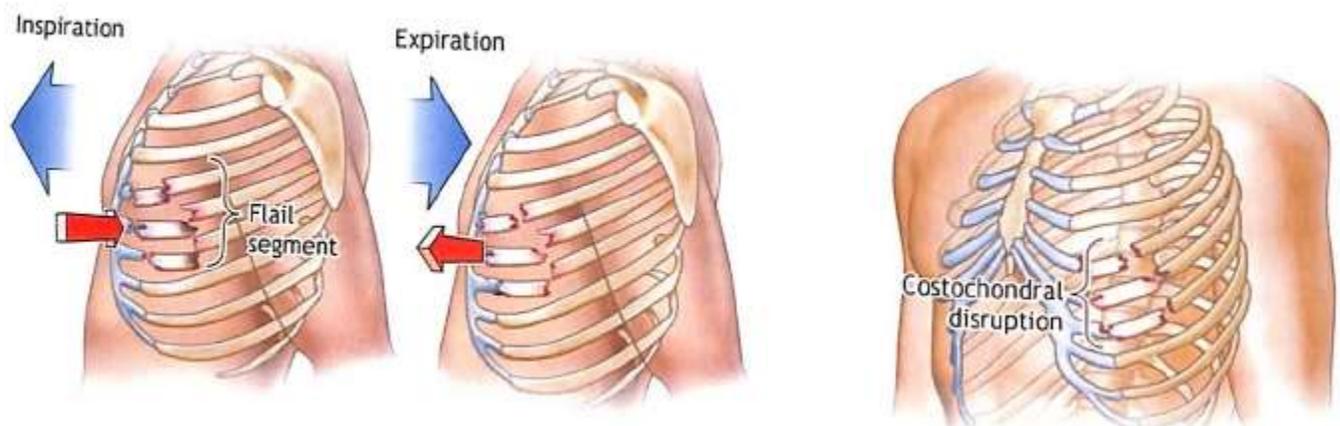
Flail segment is usually defined as at least two or more fractures in at least two or more ribs hence producing a free segment that has lost bony continuity with the rest of the thoracic cage.

This injury results in a potentially severe **impairment of ventilation**.

In addition there is usually significant underlying **pulmonary contusion**.

These two factors act to impair oxygenation and non-invasive ventilation or mechanical ventilation will often be required.

Pathophysiology



Paradoxical movement on respiration of flail segments (10th ATLS)

Although chest wall instability leads to paradoxical motion of the chest wall with inspiration and expiration this defect alone does not result in significant hypoxia.

Historically it was thought that a major contributing factor to hypoxia in flail segments was due to the “pendeluft” phenomenon. Because of the loss of chest wall integrity the involved lung paradoxically collapses on inspiration and expands on expiration.

The pendeluft theory suggested that expired air from the normal lung simply crossed the carina and filled the injured (abnormally expanding) lung, and then this air returned back via the carina (un-oxygenated) to the normal lung on inspiration. This to and fro motion, between injured and normal lung was thought to create a significant functional dead space. It is now thought however that the pendeluft mechanism is **not** a clinically significant factor in hypoxia in flail segments.² This is an important point as “strapping” the chest wall was once advocated in combating this mechanism. Strapping is however contra-indicated due to the further impairment to ventilation that this brings about.

Current thinking about the mechanism of hypoxia in flail segments relates to three important factors:

Impairment of effective ventilation is due to:

- **Pain, with reduced respiratory effort.**
- **Reduced lung expansion on inspiration**, (a segment of the chest wall that is flail is unable to contribute to lung expansion).
- The underlying **pulmonary contusion** that is associated with these injuries.

A flail segment is *more likely to occur in elderly patients*, as they have less compliant chest walls than is the case for younger patients.

Clinical Assessment

1. Vital signs:

- In particular, respiratory distress, tachypnoea, tachycardia, laboured breathing.
- The patient may be **hypoxic** to a varying degree.

2. Pain is usually severe.

3. Paradoxical chest wall movement:

- In smaller flail segments or patients in significant pain, (and hence splinting) this sign may not be readily clinically detected, because of chest wall splinting.

Chest wall movement may seem simply asymmetrical and uncoordinated. Often this sign will be better appreciated on palpation rather than by direct inspection.

- Classically however a flail segment will demonstrate paradoxical movement of the involved segment, whereby the involved lung paradoxically collapses on inspiration and expands on expiration.

The important *differential diagnoses* for paradoxical chest wall movements include:

- Flail segment
- Upper airway obstruction

- Spinal cord injury, (after C5 and at the upper thoracic segments, ie an intact phrenic nerve, but with loss of intercostal nerve function).
4. Crepitus:
- Some degree of crepitus will commonly be detectable on palpation.

Investigation

Bloods tests:

1. FBE
2. U&Es/ glucose
3. Cardiac enzymes, (associated myocardial contusion)
4. Blood group and cross-match

ECG:

As there may be associated myocardial contusion.

Plain Radiography

Plain CXR may demonstrate multiple ribs fractures, but may not show costo-chondral separation.

The presence of a flail segment may not be appreciated on plain CXR.

Associated pulmonary contusion is an important association with this injury. It may be seen on the plain CXR, however, the true extent of contusion may not be apparent and its radiological appearance may be delayed.

See Appendix 1 below.

CT scan:

CT scan of the chest imaging modality for any suspected flail segment particularly in any patient who has required intubation.

CT is far more sensitive in defining the true extent of a thoracic injury than plain radiography

In particular it will be better able to:

- Define the numbers of ribs fractured including any injuries through the costal cartilages not seen on plain radiography.

- The degree of pulmonary contusion, which may be underestimated by plain radiography
- Detect pneumothorax
- Detect haemothorax
- Detect associated injuries such as traumatic rupture of the aorta, or rupture of the diaphragm, (not seen at all on plain radiography).

The decision to do a CT scan of the chest will depend on how extensive the patient's injuries are, how unstable they are as well as the degree of index of suspicion for other complications or associated injuries.

See Appendix 1 below.

Echocardiography:

If any associated cardiac injury is suspected.

Management

1. ABC:
 - As in any multi-trauma, attention should be paid to any immediate ABC issues.
 - Cervical spine precautions as clinically indicated.
 - Large flail segments will have significant underlying pulmonary contusion, and respiratory deterioration will be inevitable. Early intubation should be considered.
2. Establish monitoring:
 - ECG.
 - Pulse oximetry.
 - Non-invasive / invasive arterial line blood pressure.

Following initial stabilization the two most important issues to be addressed will be adequate oxygenation and pain relief.

3. **Oxygenation:**

Oxygen therapy:

- All patients should receive supplemental oxygen, via facemask. This may be all that is required in young, otherwise healthy patients without significant cardiovascular or respiratory co-morbidities and who have lesser degrees of injury.

Patients who are older, have more cardiovascular or respiratory co-morbidities, and especially those with more extensive injury will require more aggressive respiratory support, either in the form of non-invasive ventilation or intubation and mechanical ventilation.

Non-invasive ventilation:

- This may be tried in the first instance, for injuries that are not too extensive.

Intubation and ventilation:

- In most cases it is the severity and extent of the associated lung injury that determines the clinical course and requirement for mechanical ventilation
- Ventilation is usually necessary only until the resolution of the pulmonary contusion. Healing and stabilization of rib fractures is rarely the limiting step in weaning from mechanical ventilation, except in the most severe chest injuries.

4. Fluid resuscitation:

- Fluid resuscitation must, as in any major trauma, correct any hypotension.
- It should be cautioned however that contused lung is also sensitive to over-hydration and if this occurs, an ARDS types picture may result.

5. **Analgesia:**

Analgesia will be the cornerstone of treatment for rib fractures. This will assist in allowing ventilation, otherwise restricted by pain.

Options include:

Parenteral analgesia:

- Initially titrate IV opioid to clinical effect.

PCA infusions:

- Patient controlled administration of an opioid infusion (PCA) is the best method for cooperative patients who are able to manage this man.

Patients who are older, have more cardiovascular or respiratory co-morbidities, and especially those with more extensive injury will require more aggressive measures to control pain.

Intercostal nerve blocks:

- For two or three rib fractures, in younger patients without significant co-morbidities posterior rib blocks may be adequate to control pain.

Intra-Pleural anaesthesia:

- Anaesthetic introduced into the pleural space.

Epidural Infusion:

- The best analgesia for a significant chest wall injury is a continuous epidural infusion of a local anaesthetic agent and/ or opioid.
- This provides excellent analgesia allowing for effective ventilation and coughing without the risks of respiratory depression.
- Epidurals may be placed in the thoracic or high-lumbar positions.

Serratus Plane Block:

- A newer technique done under ultrasound guidance, can give good multilevel rib and chest wall anaesthesia.

6. Intercostal catheter:

- Is indicated if there is associated pneumothorax or hemothorax.
- This is also particularly important in any patient who is to be intubated or receive non-invasive ventilation.

7. Surgery:

The popularity of surgical fixation of flail segments has varied over previous decades.

Currently mechanical ventilation is usually preferred to surgical fixation of large flail segments.

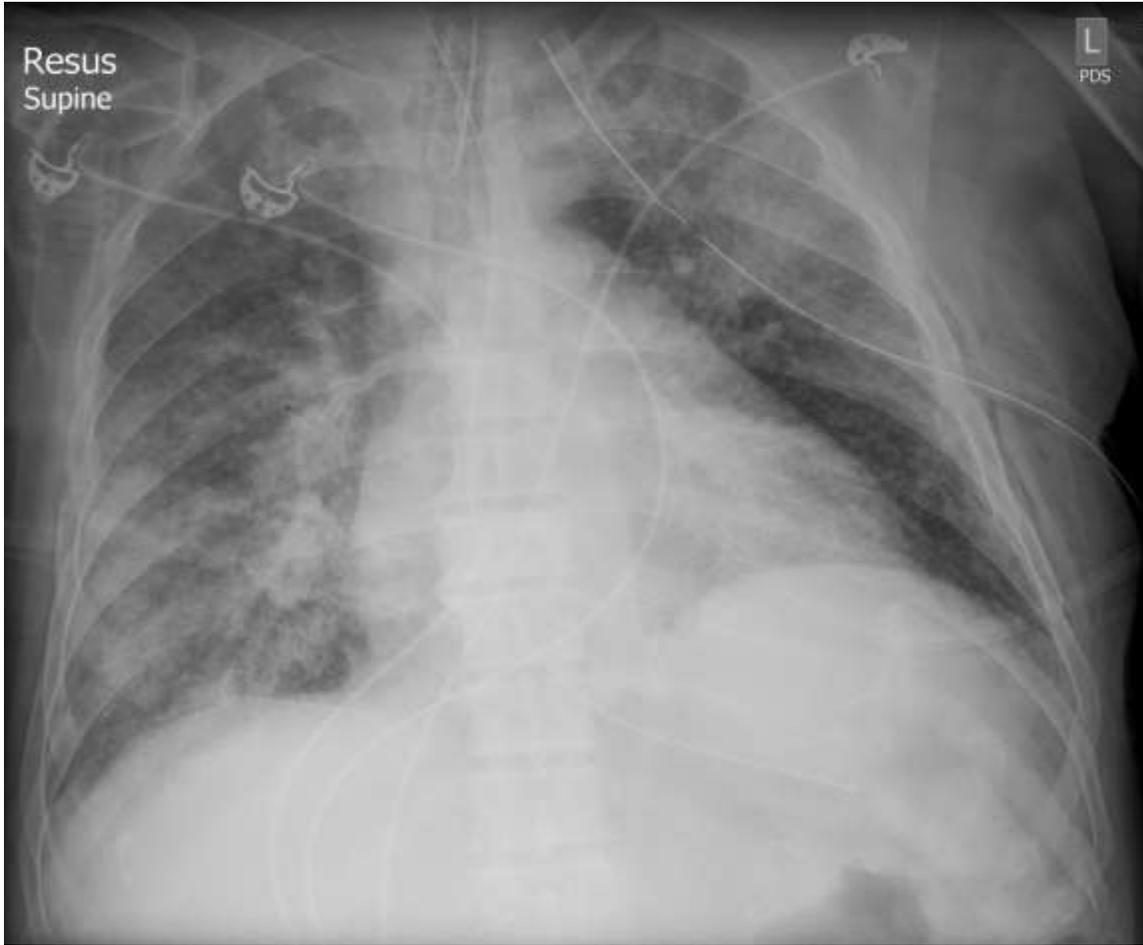
Positive pressure ventilation essentially provides an “internal stabilization” to the thoracic cage as well as providing oxygenation and ventilation for the management of pulmonary contusion and so has largely replaced the need for surgical fixation.

Disposition

All patients with a flail segment injury should be referred to the:

- Thoracic Surgical Unit
- HDU/ ICU.

Appendix 1



CXR in a 59 year old male who had sustained a severe crush injury of the chest. This patient had a large flail segment of the left, and extensive bilateral lung opacifications indicating pulmonary contusions, (Northern Hospital).



Coronal CT scan of the chest of the patient above, showing extensive bilateral pulmonary contusions. The injury is far more apparent on CT than on plain radiography.

References

1. 10th ATLS Manual, 2017.
2. OH TE, Intensive Care Manual, 4th ed 1997, p. 594

Dr J. Hayes
Reviewed June 2018.