A re-conceptualisation of acute spinal care

Mark Hauswald

ABSTRACT
The emergency care of patients who may have spinal injuries has become highly ritualised. There is little scientific support for many of the recommended interventions and there is evidence that at least some methods now used in the field and emergency department are harmful. Since prospective clinical trials are not likely to resolve these issues I propose a re-conceptualisation of spinal trauma to allow a more rational approach to treatment. To do this I analyse the basic physics, biomechanics and physiology involved. I then develop a list of recommended treatment variations that are more in keeping with the actual causes of post impact neurological deterioration than are current methods. Discarding the fundamentally flawed emphasis on decreasing post injury motion and concentrating on efforts to minimise energy deposition to the injured site, while minimising treatment delays, can simplify and streamline care without subjecting patients to procedures that are not useful and potentially harmful. Specific treatments that are irrational and which can be safely discarded include the use of backboards for transportation, cervical collar use except in specific injury types, immobilisation of ambulatory patients on backboards, prolonged attempts to stabilise the spine during extrication, mechanical immobilisation of uncooperative or seizing patients and forceful in line stabilisation during airway management.

INTRODUCTION
Almost one million patients are evaluated for spinal injuries every year in US emergency departments alone. Only 2–5% of these patients actually have spinal injuries, most of these are stable and few unstable injuries are actually missed. However, failing to treat an injury that later causes disability is among the greatest fears for emergency providers. Unfortunately few acute treatments for spinal injuries have been subjected to controlled clinical trials and the emergency care of patients who may have spinal injuries has become highly ritualised. Since the evidence that current care is effective is very limited it relies primarily on historical comparisons. The only study that compared patients with blunt spinal injuries who received routine emergency spinal care with those who did not was done internationally and showed that patients who received prehospital care had worse outcomes an association that remained after correction for mechanism of injury. This does not mean that all treatments are useless but it is clear that at least some methods commonly used in the field and emergency department can cause harm. For example, in patients with penetrating injuries standard care is associated with a doubling of the mortality rate. Adoption of newer techniques of spinal care has been slow. One reason is that acceptance of an innovation does not occur until individuals believe that the innovation is reasonable. This requires a theoretical model that is compatible with the proposed change. The generally accepted theoretical model of preventable post injury neurological deterioration is that visible movement of the spine as a unit is an adequate surrogate for movement at the injured site and that movement at the injured site causes unstable segments or sharp bony fragments to ‘cut’ the cord. This leads to an emphasis on ‘immobilisation’ that is, restricting gross motion. I will show that this model violates accepted principles of injury mechanics and elementary physics and propose a re-conceptualisation of spinal trauma to allow a more rational approach to treatment.

To do this I analyse the basic biomechanics, anatomy and physiology, epidemiology and physics involved. I then develop a list of recommended treatment modifications that are more in keeping with the actual causes of post impact neurological deterioration than are current methods.

BIOMECHANICS
The spine consists of a complex structure of interlocking and reinforcing parts. Bones and intervertebral disks are held together by a self-reinforcing system of ligaments and muscles. The entire structure comprises a complex set of energy adsorbing struts. Components fail at about the same level of force, a feature that maximises strength while minimising mass. This means that most injuries are minor (no permanent failures) or catastrophic (multiple irreversible failures including the cord) and hence that the majority of trauma patients will not benefit from emergency spinal care. The normal range of motion is essentially synonymous with the amount of non-destructive distortion tolerated by the structure and tissues. It requires almost no energy to move the spine within this range. Since resistance to movement is near zero in uninjured segments, resistance cannot be significantly less in injured areas and it will generally be greater due to preloading of tissue by oedema, spasm and mechanical impingement. Injury models that ignore these facts give results that are not directly comparable to the clinical situation. These include cadaver models in which iatrogenic injuries have been made after rigour mortis has developed (in which the uninjured segments are more stiff and the injured segments less stiff than they are in life) and models in which movement exceeds the normal range of motion. It is only when the normal range of motion is exceeded that excess energy can cause tissue destruction (and motion) at the damaged segments. This does not mean that bone fragments cannot cut the cord but rather that this will occur when the normal (near
zero resistance) range of motion is exceeded and force is directed at the injured site.

Energy deposition is very different during and after a crash. An injury sequence usually involves rapid deposition of very large amounts of energy. In addition, during the ‘accident’ episodes of energy deposition tend to be repetitive—as when an unrestrained driver goes through a window and then bounces across the vehicle and road. Since energy is absorbed during each impact, the maximum energy deposition and hence injury, will tend to occur early in the sequence. This is obvious for a restrained driver, whose head will be subjected to the greatest deceleration during the initial impact and will then undergo a series of decreasing oscillations but even a direct blow can generate repetitive linear accelerations that are hundreds of times greater than gravity. Energy depositions during extrication and emergency care are orders of magnitude less than that of the primary or secondary impacts. In fact it generally takes 2000–6000 Newtons of force to fracture the cervical spine whereas even hanging a 4 kg head off the treatment table will only generate about 40 Newtons. (Gravity exerts a force of 9.8 N). Energy deposition during treatment will be far less than that during the crash sequence even after the spinal injury has occurred.

ANATOMY AND PHYSIOLOGY
Mechanically severing the cord causes irrevocable injury but both temporary and permanent neurological damage also result from other mechanisms. It is well understood that patients may deteriorate after the acute injury despite the most careful care. Neurological deterioration may be caused by tissue hypoxia which in turn may be from global hypoxia, damage to the blood vessels feeding the cord itself, microvascular injury or compression by oedema. Cord injury from hypoxia or direct contusion causes a complex series of physiological changes that can result in apoptosis and cell death.

The current theory of post accident neurological deterioration functionally assumes that spinal instability is an all or nothing phenomenon, that unstable injuries lose all their resistance to movement. But this is clearly not true. Steadman’s dictionary defines spinal instability as ‘the inability of the spinal column, under physiological loading, to maintain its normal configuration [which] may lead to damage to the spinal cord or nerve roots or to painful spinal deformity’. Most spinal injuries are actually biomechanically stable, at least in the short term. Some of these patients will become biomechanically unstable over time as tissue oedema resolves and if the injured part is subject to prolonged periods of gravitational force, but this does not change the fact that initial immobilisation-directed treatment will not affect their ultimate outcome.

EPIEDEMOLOGY AND LONG TERM TREATMENT
As a general principle, reduction of tissue hypoxia is the most important basic factor in trauma management. This often requires sophisticated treatments such as advanced airway management, blood transfusions and surgery that are only available in hospital. Delaying definitive care to provide spinal ‘stabilisation’ can harm even those patients who have biomechanically unstable partial spinal injuries and cannot help the large majority of trauma patients who have either intact spines or irreversible injuries. Fortunately many cord injuries improve as oedema resolves. This means that the assumption that care or the lack of it in a specific case caused improvement or deterioration is generally unwarranted and does not provide evidence for or against current practice. Patients at risk for spinal trauma are likely to have other critical injuries that require urgent management. Those with cord injuries are particularly prone to hypoxic tissue damage in the immobile and de-sensate areas below the spinal injury. In fact decubiti are a leading cause of morbidity and mortality in these patients. Both the potential soft tissue damage and the possibility of delay in critical care provision mean that harm as well as potential benefit from spinal treatment needs to be considered.

IN SUMMARY
1. Far more patients will be treated than eventually turn out to have injuries to their spine.
2. Most patients who do have spinal injuries are mechanically ‘stable’ at least in the short term—stable in that significant force would need to be applied to the injured site to cause further damage.
3. Completely unstable injuries—ones that have essentially no more resistance to movement than do the uninjured segments generally cause irreparable injuries during the ‘accident’ sequence.
4. Unfortunately all of these patients are at risk for side effects of treatment.

PHYSICS
Analysis of the physics involved in spinal care allows the development of a more scientifically valid theory to guide therapy. In Newtonian physics motion over a distance (d) is one component of energy (E), the other being force (F): E=Fd. Force is defined as mass (m) times acceleration (a): F=ma. To change a physical system, energy must be deposited or equivalently mechanical work must be done. In the case of biomechanical injury during a vehicle crash, the head, neck and body de-accelerate at different rates. The resultant kinetic energy is transferred to the injured part causing direct and indirect tissue damage. These principles mean that movement cannot cause injury by itself because force must be involved to generate (or change the form of) energy. This has important implications for the medical literature which has concentrated on attempts to measure and decrease post injury motion without considering the amount of force that is needed to cause the movement. This approach does not necessarily result in minimising the energy of the system or hence the amount of potential tissue damage. The goal of post impact spinal care must be to minimise energy deposition to the tissues that were injured, this requires that force and hence energy be minimised at the injured site. In other words the total energy of the system needs to be minimised and/or the energy that is generated during care needs to be absorbed by sites away from the injured tissue.

IN SUMMARY
1. Reducing visible spinal movement does not necessarily reduce movement at the injured site both because movement at uninjured sites requires minimal force and because force applied at the injured site may not cause gross movement of the rest of the spine.
2. Mechanical work at the injured site will by definition be minimised by minimising force and energy there.
3. Mechanical work can increase injury but movement per se cannot.

The above principles allow the development of a rational, scientifically based approach to the care of the potentially spinaly injured patient which will at times be different from current treatment. Prehospital and emergency department care should
focus on minimising force and hence energy deposition to the
parts of the spine likely to be injured. Movement within the
normal range of motion is much less important because it by
definition requires essentially no force and will hence occur at
uninjured segments. Global hypoxia should be aggressively
treated. Local tissue hypoxia should be avoided. Delays to
definitive treatment should be minimised. This approach
can be used to guide analysis of several specific treatment
interventions.

The use of a comfortably firm, high friction surface for trans-
port is rational. Comfortable means, by definition, that it
would not cause tissue hypoxia.13 High friction means that the
energy generated during transport will be dissipated over a
large area. Hard slippery ‘backboards’ expedite extrication but
are terribly unsuited for prolonged use. Their low friction
surface requires that all the energy generated during transport
is absorbed by direct restraints such as straps and lateral sup-
ports. Because these attach to the patient in areas that have dis-
ferent resistance (the head is much less compressible than the
torso) some of the energy will inevitably be deposited across
the injured site. Tightly fastening the restraints will decrease
this energy deposition but at the expense of constricting the
patient and potentially causing hypoxia.14 Using a device such
as a vacuum board that allows energy generated during trans-
port to be dissipated over a large area is increasingly popular
as a vacuum board that allows energy generated during trans-
port without

The focus on reducing visible movement is least rational
when treating an uncooperative or seizing patient. Tightly
strapping these patients down does nothing to reduce the force
they generate and in many cases will increase it if they panic
or fight the restraints, either voluntarily or involuntarily. These
patients may need to be calmed down, sedated or paralysed but
transport without ‘immobilisation’ is much preferable to
increasing their leverage by tying them up.

Airway management of patients in whom spine injuries
cannot be excluded is controversial. All methods of advanced
airway management put force across the cervical spine and
move it. In fact bag valve mask ventilation moves the spine,
and hence delivers more energy to it, than careful intubation
does.15 However, the movement remains within the normal
range of motion and requires little energy overall. Most authors
recommend in line ‘stabilisation’ in an attempt to minimise
visible movement but this may make intubation more diffi-
cult20 and can increase the amount of force delivered.21 In fact,
immobilising the head directs more of the force during intub-
ation to the neck. Having an assistant hold the head and
manipulate the airway if necessary may make intubation easier
and is generally reasonable but if they must apply significant
force to keep the head immobile this means that an equal or
greater force is being applied by the operator and this violates
the basic principle that force across the injured site should be
minimised. If the head must be repositioned to successfully
manage the airway, this is preferable to a ‘tug-of-war’ between
the person holding the head and the one doing the intubation.
In line traction should be condemned for the same reasons that
overly aggressive in line stabilisation is and because it applies
a distractive force much like a cervical collar does.

LIMITATIONS

Acutely biomechanically unstable spine injuries that have not
already caused irreversible injuries are the only ones that can
benefit from emergency care. These are very rare. As a conse-
quence, adequately clinically testing any therapy is extremely
expensive. Relying on tradition does have advantages. It is easy
to remember, non-controversial and minimises medical legal
risk—at least in the short term. Change is only worth doing
when the estimated benefit exceeds the risk and additional
cost. In the long run the relatively simple recommendations
above are likely to meet these criteria by simplifying spine care,
decreasing time to definitive care and minimising additional
injury during transport and in the emergency department.

CONCLUSION

I use the term ‘theory’ as both an explanatory and a predictive
model but in this case one that is accepted as elementary
Newtonian mechanics. Within the context of spinal care
neither the ‘theory’ that motion causes injury or the one dis-
cussed above has been ‘proven’ but the fact that the former vo-
lates aspects of Newtonian mechanics means that it is at best
only partially correct. In that motion which occurs at the
injured site does obviously increase injury it is a valid explana-
tory model but it is incomplete and in some cases leads to
standard therapies that can be safely discarded. Specific treat-
ments that are irrational when examined from basic principles
include the following: the use of hard ‘backboards’ for transpor-
tation, cervical collars except in specific injury types, immob-
islisation of ambulatory patients on backboards, mechanical
immobilisation of uncooperative or seizing patients and forceful
head stabilisation during airway management. Eliminating
these treatments will decrease time to definitive treatment,
reduce the risk of ischaemic tissue damage and simplify airway management. It will make emergency care more comfortable for patients and decrease iatrogenic injuries. Re-conceptualising the guiding principle of acute spinal care in terms of minimising energy deposition rather than minimising visible motion may allow more rapid adoption of newer treatment modalities.

Given that this is an area in which acceptance of even minor changes has been exceptionally slow22–23 there is a potential to greatly improve patient care.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES
A re-conceptualisation of acute spinal care

Mark Hauswald

*Emerg Med J* 2013 30: 720-723 originally published online September 8, 2012
doi: 10.1136/emergmed-2012-201847

Updated information and services can be found at:
http://emj.bmj.com/content/30/9/720

These include:

References

This article cites 19 articles, 1 of which you can access for free at:
http://emj.bmj.com/content/30/9/720#BIBL

Email alerting service

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections

Articles on similar topics can be found in the following collections

Trauma (991)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/