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# Working for Safety:

## How medical and safety research leads to safety improvements in motor sport

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Driving safety forward with research based innovative change from driver seat design, seat impact attenuation and prevention of injury on impact.

Managing regulatory change in light of findings.

# Introduction

The invention of the car transformed society and made the world a smaller place. This world became smaller still as we removed the man with the red flag walking in front of the car to enable us to travel faster. It wasn't long before the human competitive spirit took hold of the industry and racing started. The first recorded internal combustion auto racing events began soon after the construction of the first successful gasoline powered automobiles in the 1880s.

Considered the world's first motoring competition, the 1894 Paris to Rouen competition for horseless carriages saw 102 competitors for a 10 Franc entrance fee. Sixty-nine cars started the 31 mile selection event and 25 'easy to drive, not dangerous' vehicles were selected for the main event. Further racing events were staged before 1900 in both France and the United States of America before the first auto racing venue was established in Nice, France in 1897, called 'Speed Week'.

At this early stage, racing was essentially city to city with the first purpose-built racing circuits established in Australia (Aspendale) in 1906 and the UK (Brooklands) in 1907 largely as a result of racing falling out of favour after nine fatalities in one event in 1903 in Bordeaux, France caused the French Government to ban open-road racing.

So, we can state that motor sport is dangerous. It always has been. Thankfully, with each passing year the risks are falling. High profile competitions such as Formula 1 historically get the most publicity with the 1950s to 1980s being the period of highest risk in living memory. The deaths of Roland Ratzenberger and Ayrton Senna at Imola in 1994 in the same weekend shocked the motor sport community and later led to safety changes, such as raised cockpit sides, a head and neck support (HANS) device and, considered a positive contribution at the time, the rigid extractable driver seat [1]. Formula 1 remained fatality free until the death of Jules Bianchi in 2014 at Suzuka and remains so since then to the time of writing.

Serious injuries and fatalities in motor sport are multifactorial. Often there is a combination of factors at play, be it inclement weather, surface conditions, vehicle construction, circuit or rally route design or simply just poor luck. Energy equals half the mass multiplied by velocity squared. The forces in the accident either go through the driver or they don't. Vehicle design with a rigid monocoque or safety cage and energy absorbing crumple zones can dissipate the energy and protect the occupant. As technology and design improves, the grey area in the middle between uninjured and severely injured is narrowed. What this means is that when immediate care is needed at the accident scene, it is no longer acceptable to just send a doctor.

Evolution in the care of accident victims has moved at pace in the last 20 years with adoption of the wider multidisciplinary team approach with individuals working together in the pre-hospital environment using their particular skill set in collaboration with others being the norm in developed societies since just 2011 (UK). In the last 2 years alone, the FIA Medical Commission, backed by the FIA Safety Committee, has passed regulation to ensure this combination skilled approach is mirrored in motor sport across the board.

This white paper seeks to illustrate how research into current practice, driven by evidence or need, leads to change in vehicle and safety system design, pre-hospital immediate care and prevention of injury and how this leads on to change in the future structure of racing vehicles and driver safety systems and rescue procedure.

We highlight and emphasise a revolution in driver seating, research-led reaction to the finding of increased incidence of hand injuries, an evidence-based review of impact warning indicators and a wholesale reform of the methodology of driver assessment and treatment after an accident. Being both proactive and reactive in this way, working constantly to improve, based on evidence, not just experience, makes motor sport safer.

# Driver seat design

The extractable 'Lear' seat, introduced in Formula 1 in 1999, was designed to reduce spinal movement during extrication. However, advancements in safety, extrication procedures, and driver protection systems have rendered it obsolete. Current research and real-world extrication scenarios demonstrate that the extractable seat introduces unnecessary risks, delays medical intervention, and is no longer the safest option. There is compelling evidence that motor sport safety has evolved beyond the need for extractable seats and supports the immediate transition to modernised extrication protocols [2].

Use of the extractable seat is dependent on many factors such as:
The seat remaining intact, not being buckled or entrapped by the accident.
The seat straps being correctly folded and attached behind the seat by the teams.
Knowledge of the seat mounts and attachments which differ between F1 teams and single seater series.
The car being accessible on both sides, upright, not on fire and not an electrically 'red' car.
The driver having an isolated non-time critical spinal injury and no other significant injury.
The driver not requiring mechanical disencarceration with tools.

## *Key Issues and Limitations of the Extractable Seat*

Reduced Need for the Seat Extrication Process
With the advent of safer cars and barriers since 1999, the 'grey area' where a driver is harmed, rather than uninjured or critically injured has narrowed. In the vast majority of cases, the energy released in the accident has not caused injury and the driver self-extricates. Where the driver has suffered significant force and is critically injured, there is a medical need for rapid extrication and swift delivery to definitive care. Where extrication is required, it is therefore much more likely to be rapid, without extracting the seat. Furthermore, in closed cars, the seat is never extracted and the injury pattern can still be severe and the driver extrication process using other methods is acceptable.

### *Increased Spinal Movement and Injury Risk*

The extractable seat was originally designed to minimise spinal movement during extrication. However, research has shown that self-extrication or manual removal using modern techniques results in less spinal displacement than lifting a driver in an extractable seat [3]. Additionally, spinal injuries naturally trigger muscle spasms, which help stabilise the spine, making prolonged immobilisation unnecessary. Medical consensus now favours rapid extrication for critical cases over extended stabilisation techniques. It should be noted that if extracted in a seat, the driver still needs to be removed from it in order to be further assessed and treated. Typically, this requires rescuers to hold under the axillae and knees while the seat is dropped away. There is immediate body weight induced spinal flexion which is then reversed causing extension when placing the driver supine. This practice negates the whole seat extrication process and can be avoided if using a short board or Boa technique for extrication.

Another more urgent consideration is that the Lear extractable seat requires the use of a cervical collar to secure the c-spine in order to use the seat as designed. Best practice now advises against the use of a cervical collar except in rare cases. In any case, the device is considered an extrication tool, to be removed after extrication if used at all, and no longer mandated. There is a risk that it may cause harm in some cases, and so, to use the extractable seat necessitates the use of a device that may cause harm and this is indefensible medico-legally [1,3,4].

### *Delayed Medical Response and Treatment Complications*

Extrication using an extractable seat can typically take 6 to 10 minutes or much longer in the accident situation, significantly delaying critical care for head trauma, internal bleeding, and chest injuries that require immediate intervention [5]. Modern emergency protocols prioritise rapid access and stabilisation, favouring quick extrication techniques over prolonged spinal immobilisation unless absolutely necessary. FIA extrication exercises have consistently shown that alternative techniques, such as the Boa extrication device and short board methods, allow for faster, more effective medical intervention [2]. Short board or use of the Boa device allows safe extrication with less spinal movement than the extractable seat in 2 minutes, as demonstrated in the 2025 FFSA extraction seminar edition.

### *Structural and Compatibility Issues with the Halo*

The extractable seat was developed before the introduction of the Halo device in 2018. Lifting a driver over the Halo introduces additional spinal movement and extends extrication time [6]. Given that the Halo is now a permanent safety feature in open wheel series racing, maintaining an extractable seat only adds complexity and potential risk. The requirement to lift the extractable seat vertically over the Halo structure adds mechanical instability during removal. It is also a challenge for rescuers and increases the likelihood of injury in rescue staff.

### *Consideration of the HANS Device*

The extractable seat was introduced in 1999 and HANS device in 2003. Better head and neck support has led to fewer cervical spine injuries. The HANS device reduces neck tension, shear and total neck load significantly. The extractable seat extension slot to stabilise the c-spine was designed before the HANS device was in common use [1,2].

## *Seat Entrapment Issues and Regulation-Driven Problems in Formula E*

Formula E regulations require the combined weight of the driver and seat to be at least 80kg. If a driver is underweight, ballast is added behind the top of the seat, often leading to extraction difficulties and seat entrapment [8]. Several FIA extrication exercises have demonstrated that ballast positioning has caused seat entrapment and delayed seat removal, contradicting the goal of safe extrication. Formula E's regulatory-driven seat modifications have created additional extrication difficulties, further emphasising the need for an alternative approach. Equally, extrication teams avoid the seat removal method when the car is electrically unsafe or 'red' as there is increased risk of electrical conduction and the procedure exposes rescue staff to risk for longer.


## *Expert Consensus on Better Extrication Methods*

Medical professionals and FIA extrication teams increasingly favour alternative extrication techniques over extractable seats. The Boa extrication device and short board techniques provide quicker, safer options, requiring fewer rescuers and minimizing spinal movement [2]. FIA training exercises have consistently demonstrated that the extractable seat introduces unnecessary steps, additional handling, increased movement and prolonged time to definitive care risking decreased survivability.

The extractable seat is an outdated and unnecessary safety device that has been superseded by modern safety innovations and extrication techniques. Evidence overwhelmingly supports moving away from extractable seats [1-5,7]. The continued use of extractable seats increases spinal injury risk, delays medical intervention, and complicates extrication in modern open-wheel cars.

In April 2025, presented with the evidence for change, the FIA Medical Commission voted unanimously to remove the requirement for extractable seats in single seater cars. The transition away from extractable seats to fixed seats with aligns with current scientific research and medical best practice, ensuring the continued protection and safe extrication of drivers in open wheel FIA series racing environments.

## Driver seat energy attenuation

Whereas in single seater cars a driver is in the horizontal lying down position in the main, in cross country cars, which are based on road production vehicles, the driver is more vertical. The seats in rally vehicles are bolted to the floor of the car with specialised mounts. This fixed and rigid mount allows the driver to feel feedback from the car enhancing reactivity and control but also leaves the driver vulnerable to high impact forces. When the car impacts the ground after a jump, the force is transmitted in the z-axis upwards through the vertebral column or in the case of a 'nose in' impact, an x-axis stop with y-axis rotation before a z-axis final impact.

It is quite common to record significant g-load in these vehicles, in particular in cross-country rally events, which by nature of the competition leads the car to leave the ground periodically or the nature of the terrain can take a driver by surprise with dips and large drop offs. The author has been Chief Medical Officer of a World Championship cross-country event for almost 20 years and has witnessed many vertebral fractures in this discipline, often recording 3 or 4 medevac flights per event for the similar spinal injuries. Good immediate care leads to a good outcome for the injured party, but prevention is better than cure in these cases.

The FIA Safety Department has developed a seat attenuation device – a shock absorber that the seat is mounted on – to mitigate the g-forces on impact.

## Prevention of hand injuries

The 2023 season of Formula e saw at least 9 serious hand injuries, leading to time out of competition for the drivers involved. A pattern became evident, with video analysis, driver interview, crash mechanism and vehicle structure under the spotlight. It became evident that on impact, typically when a car hits another from behind, the front wheels of the car impacting were thrown into a rapid steering action. This span the steering wheel (which is square shaped) at speed causing the hand to impact with the wheel itself, or in most cases with the monocoque side wall leading to metacarpal fracture.

The FIA Safety Department investigated these injuries in detail, studying the mechanism. Immediate mitigation was required and component redesign, to allow the safe continuation of the discipline until a complete chassis redesign for the generation 4 cars.

A decision was made to move the steering wheel further forward towards the driver, where the monocoque is wider to allow more space for the hands. 5mm of energy absorbing padding was added to the cockpit sides in line with the edge of the steering wheel. Firmer, energy absorbing armoured gloves were trialled. This lowered the number of hand injuries in the 2024 season to 3, a significant improvement but not definitive enough.

Further work was done to stiffen the front wing on the Formula e cars and in parallel a steering column damper was designed and implemented, mitigating the rapid steering wheel rotations on impact. The problem has been largely engineered out using science and engineering to prevent a medical problem. This is the perfect example of Safety, Medical and Technical departments working together in one building on the same floor in one combined area to solve a pressing problem. There were no hand fractures in the 2025 Formula e season.


## The impact warning light

Previously known as the 'medical light' and now retitled to 'impact warning light', the evidence for this safety device was studied by the FIA Safety Department in conjunction with the FIA Medical Commission. The light is a slowly pulsing blue light that sits forward of the driver in single seater series or elsewhere in other series. An impact (on the car) of over 15g in the x-axis and y-axis or over 25g in the z-axis for >5ms will activate the light causing it to flash rapidly.

Designed as a tool to aid in the medical decision-making process and a measure of accident (crash pulse) severity, the rule was that the driver should be examined in the medical centre if the light was triggered, thus creating a medical threshold, which was enforceable. Testimony from Chief Medical Officers seemed to indicate that often the light was triggered, and the driver was obviously uninjured. Occasionally the light was not triggered, and the driver did have an injury such as concussion or a minor orthopaedic injury. It was not uncommon to record spurious high g-load readings that would be expected to lead to injury, but the car remained intact and competing continued.

A study of the evidence was undertaken in 2021. 30 accident cases were analysed over 3 disciplines – Formula 1, Formula e and WRC. The general medical information and outcome was compared to the accident data recorder report for each case, taking into account accident severity metrics, the aim being to define the threshold for the medical light activation that clearly indicates a likely injury or injury suspicion. No clear trend was defined. The device is triggered when the required force goes through the car, not the driver.

Once it was established that the medical light was not useful in predicting injury or in any way correlated to the medical outcome, the FIA Medical Commission voted to 'demedicalise' the light, renaming it 'impact warning light' and removing the mandatory requirement for the driver to attend the medical centre if the light was triggered. Clinical acumen is the most important skill in driver assessment. This includes pre-hospital immediate care skills and experience, with up-to-date training. In emergency medicine, there is no real substitute for lifting the visor, eyeballing the driver, performing an initial assessment and making a clinical decision.

## The pre-hospital multidisciplinary team

In the early days of motor sport competition, there was no medical care at the venue. This changed when the founding fathers of motor sport medicine, Dr Jean-Jacques Issermann and Dr Sidney Watkins both established medical teams in their respective countries, essentially doctor based, to be present at race meetings. First set up in the medical centre, later in medical cars to respond on track and eventually to medical cars that chase the first lap of a race as the risk of an accident is highest at that time.
These well-established teams became the norm and were very doctor-centric, the public and medical thinking being that if there was a doctor present, an injured driver was going to get the best treatment. While well intentioned, and indeed with reasonable success, this 'doctor knows best' model is not the best way ensure the highest survival rate in trauma. The treatment of accident victims has moved on with the evidence base and the immediate care response to an accident required a rethink and update in light of best practice at the start of this FIA Presidential term. Accidents happen in the pre-hospital environment – not where most doctors work.

Evidence is clear that a trauma victim needs:
An airway and to breathe or ventilate
To stop bleeding externally or for internal bleeding to be immediately recognised
To not be further injured in the extrication process
To be delivered to definitive care as swiftly as possible

In countries where they exist, paramedics, in particular critical care paramedics, are highly trained and better at working in the pre-hospital environment and can perform these skills very effectively. Only a few specialised doctors are used to working in this way out of hospital. The large tertiary referral hospital with the whole trauma team delivers definitive care. The circuit medical centre does not. Those used to immediate life-saving procedures, rapid packaging and transport of casualties are the experts.

While doctors are used to being in charge in their usual working environment, at the accident scene, command may fall to a senior paramedic or fire officer. Every country has a fire service. Indeed, management of vehicle fluid spills, smoke and fume exposure, fire risk, vehicle stability and vehicle disentanglement and disencarceration is not a doctor skill.

Recognising the evidence that scene management is best performed by a senior fire officer, the FIA Medical Commission voted to change regulation and establish the role of the Rescue Chief in 2022. This was communicated to the ASNs around the world and further reinforced in 2024 and 2025 in the FIA Safety Week medical presentations.

It is now normal and expected that ASNs field a multidisciplinary medical and rescue team, under the command of a CMO, with the scene command by the Rescue Chief who has an overview to maintain scene safety, designate tasks to other fire-fighters and medical staff, supervise the overall priorities in terms of personnel and vehicles and maintain good communication with race or rally control. This allows the doctors and paramedics to do what they do best – the immediate care of the injured driver.

Further updated regulation in 2025, based on evidence of best practice, mandates that all senior doctors in Formula 1 and Formula e chase cars have pre-hospital qualifications by 2026 to ensure they are up-to-date with best practice, with the recommendation that all other doctors follow this skills update [9]. The above is a revolution in the delivery of immediate care to accident victims in motor sport based on the evidence for best practice.

## Conclusion

The safety of competitors, spectators, medial and also marshals and officials at motor sport events is of high importance. Safety is integral to everything the FIA does. It is only by continuing to be vigilant, reactive to problems, proactive to safety development and with an eye on the evidence base for our mission that we both keep motor sport safe and make it safer over time.

We have touched on a few examples here. Further work is always ongoing regarding competitor and circuit safety equipment, vehicle safety systems, crash structures and new innovations such as wheel covers to prevent rollovers in karting. Track and circuit safety is regulated and monitored. Competition vehicles are scrutinised and safety equipment homologated. Post incident data analysis allows for learning and development and new technologies, such as AI cameras being deployed in rally add to the overall event safety. Regular meetings take place to evaluate learning from incidents that happen around the world and, as the regulator, advise and inform ASNs on recommended changes.

Real safety keeps the sport enjoyable, watchable and both adds to and maintains the reputation of motor sport not just in the FIA World Championships but into the regional and national events. As the sport grows and powertrains evolve so does safety and regulation require updating. Skills learned are incorporated into motor sport best practice. Immediate care and rescue techniques evolve over time as the evidence changes. As the gap opens, so it is closed by the FIA Safety Department, so motor sport remains the pinnacle of how to keep things safe.

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# Author Biographies

## Dr Sean Petherbridge

Dr Sean Petherbridge MBBS MRCGP DipFMS DAvMed FRSM is a senior aviation medical examiner and Medical Director of the UK's largest Aeromedical Centre. He is also President of the FIA Medical Commission and FIA Medical Affairs Manager. A leading doctor in the safety critical world of aviation he is able to bring an evidence-based approach to safety regulation from the aviation world to the motor sport world. His work has led to rapid change in motor sport medicine, building on the past achievements of motor sport medicine's founders while adding significant pace to overdue reform. The revolution in the driver seat extrication procedure and swift changes in the immediate care and management of the accident scene are an illustration of this. Respected and trusted, he is enabling a high degree of autonomy in medical and rescue staff around the world while raising standards and reflecting that in regulatory changes that both improve safety and work in practice.

Dr Petherbridge lives in the UK and works in the Aeromedical Centres in London, Gatwick and in the FIA Geneva office. He has 20 years experience in motor sport medicine at international competition level.

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