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AUTO+ MEDICAL

GETTING PHYSICAL

How F1 drivers have prepared for the increased physical demands of the 2017 cars

AUTO+MEDICAL

Contents

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Welcome to the new issue of AUTO+Medical, which features the latest news and reports from the world of motor sport medicine. I am delighted as a member of the publication's editorial board to present this edition.

In our cover story we examine how drivers are dealing with the physical demands of the new, faster Formula One cars. The higher G-Forces will certainly test them physically this year and those that trained well in pre-season will reap the benefits during the season.

We also speak to Dr Brent May, who has just helped to deliver the medical provisions and cover for the first race of the 2017 F1 season in his capacity as Chief Medical Officer for the Australian Grand Prix. We also look at how simulation and data analysis programmes have become key tools for modern circuit designers, espcially when it comes to safety.

In our regular Road Back feature we speak to Toyota World Endurance Championship driver Kazuki Nakajima, who broke a vertebra at a race in Spa in 2015. He explains how he returned to compete at Le Mans an astonishing six weeks later.

Our scientific article looks at the on-scene treatment of spinal injuries in motor sport.

I hope you enjoy the latest issue.

Chief Medical Officer, Singapore Grand Prix

LETTERS

In this section, we print the best letters and emails received from readers around the world. We welcome comments on articles as well as suggestions for future content. If you wish to send in a letter or email, please direct it to: medical@fia.com

Dear Editor,
In company with many friends and colleagues, I had the pleasure of attending the biennial FIA Medical Summit at the Hofburg Palace, Vienna in December last year.

As usual the programme for the Summit was a mixed bag of lectures, round table discussions and workshops.

Somewhat surprisingly, for what some might describe as a rather dry subject, by far the best workshop was that presented by Sandra Silveira Camargo and Magali Louis on anti-doping.

The format used was one of discussing "real" cases, what had happened and how this might be investigated and what penalty (if any) should be applied to the competitor concerned. They had put a lot of work in to their presentation and I thank them sincerely for that.

That led me to wonder if that type of format might be applied more widely to the Seminar as a whole?

The types of presentations that I have seen work well in the past include: -

Scenario based presentations
Where there is a panel with assigned roles such as Clerk of Course, CMO, Ambulance Coordinator, Chief Marshal, Fire Chief and Police Commander. The moderator starts the scenario narrative, pauses for input from the panel members and then progressively reveals more information for further comment etc.

Debates on Controversial Subjects
Where there are two opposing sides (e.g. the merits or otherwise of Cervical Collars!) and there are three speakers per side, a limited time for each speaker's presentation (which has been previously prepared) and a moderator who controls the debate and sums up at its conclusion.

Controversy, evolution and change are inevitable in medicine and indeed motor sport. We all should recognise and embrace that fact and be able to take part in discussions on various topics without fear or favour.

I can remember when I was a medical student being told that 50 per cent of what I was learning at that time would be obsolete within the next 10 years.

The problem was, of course, that no one told me which 50 per cent!

Dr Rik Hagen
FIA WRC Regional Medical Delegate for Asia and Oceania
Member of FIA Anti-Doping Disciplinary Committee

Editor: Thanks for your comments on the FIA Medical Summit. The FIA Medical Commission received positive and constructive feedback from many of the delegates at the event. All of this will be considered when it begins planning for the next one.

Dear Editor
I was a delegate at the excellent Medical Summit 2016 in Vienna. This is the third Summit I have attended, and I have been impressed by each. Not only is there the chance to network with colleagues and other experts with years of experience in motor sport behind them, there is the opportunity to hear detailed reviews of the previous two years' incidents in FIA-organised and other events. You also have a chance to contribute to the discussions to improve safety for the future. The Summit was invaluable; firstly to keep abreast of change, secondly to revise previous knowledge and finally to network with colleagues facing the same issues as I do in my motor sport practice around the world. Many people contributed to this excellent conference but one person who does deserve praise for the impressive organisation is the FIA Medical Affairs co-ordinator, Magali Louis, who made sure everything happened when and where it should. Thank you, Magali.

I recommend for anyone involved in medical care in motor sport to please strongly consider attending the next seminar. You will not regret it.

Dr Rowley Cottingham MB BS BSc FRCS(Ed) FRCEM
Consultant in Emergency Medicine, Brighton and Sussex University Hospitals NHS Trust
Medical Director, BodyChillz Ltd
Honorary Research Fellow, University of Brighton
Honorary Treasurer, BASICS (www.basics.org.uk)

Editor: Thanks for your comments. The positive feedback is appreciated by all of those involved with the event.

The 2016 Medical Summit welcomed motor sport doctors from across the world

GLOBAL NEWS

AMR will send staff to all NASCAR events

NASCAR INTRODUCES OFFICIAL MEDICAL TEAM

The NASCAR series has made the American Medical Response (AMR) company its official emergency medical services partner.

AMR will send a doctor and paramedic to all of the events on the 2017 NASCAR schedule and they will be situated in an on-track response vehicle alongside two of the championship's Track Services staff members. The doctor and paramedic will be called on to provide medical intervention at the scene of an incident.

Steve O'Donnell, NASCAR's executive vice president and chief racing development officer, described how the new deal would strengthen the stock car championship's medical arrangements.

He said: "This partnership further strengthens NASCAR's medical response capability, making our well-established, medical response system even better. AMR is a leader in the emergency services sector, and its doctors and paramedics add another layer of expertise to the immediate response team."

Edward Van Horne, president and chief executive officer of AMR, described how his operation would seek to collaboratively improve medical intervention practices with NASCAR.

He said: "We're excited about this partnership with NASCAR. We're going to work collaboratively with NASCAR and local teams to share best EMS practices and ensure the highest quality of care,"

AMR is a subsidiary of Envision Healthcare and is the largest provider of emergency medical transportation services in the USA.

EARNHARDT JR RETURNS FROM MAJOR CONCUSSION

NASCAR driver Dale Earnhardt Jr says he is approaching a new era of his career after missing much of the 2016 season with concussion.

The American driver crashed heavily at the Michigan NASCAR round last June and although he participated in the next three events, he sat out the rest of the season after being diagnosed with concussion – his second in four years.

Earnhardt was cleared to return to racing at the end of 2016 and made his return at the 2017 season-opening race in Daytona.

"I do feel like this is a new chapter, for whatever reason," he said. "I don't have a vision for what's going to happen. I don't know how to explain it, but it feels like a new me."

During his recovery, Earnhardt was open about his diagnosis in interviews and on social media, an approach that he believes helped to reduce his anxiety and stress-levels.

He said: "To heal from the concussion, I needed to be stress-free, to get that stress as low as possible," he said. "I worried a ton about people's perception about what my problem was. I didn't want any guesses out there. That's the reason I was so transparent."

Garry Connelly presented May with the award

DR BRENT MAY NAMED FIA DOCTOR OF THE SEASON

Australian Grand Prix chief medical officer Dr Brent May has won the FIA Best Doctor of the Season award for 2016.

The honour is one of seven FIA awards that are presented each year to officials working in motor sport, such as doctors, stewards and marshals.

May was presented with the award at the Confederation of Australian Motor Sport's annual gala in February 2017. During the event, FIA Formula One Stewards Chairman Garry Connelly handed the award to May, who is also the Chief Medical Officer for Motorcycling Australia and Karting Australia.

May described the award as "an amazing honour to receive". He added: "It was wonderful to be recognised for the work I do for CAMS as well as in my role as CMO for Karting Australia and Motorcycling Australia."

Turn to page 18 to read a full interview with Dr May.

MEKIES DELIVERS SAFETY LECTURE

FIA Safety Direcor Laurent Mekies outlined the FIA's approach to safety research as he delivered the 2017 Watkins Lecture at the Autosport Show in Birmingham, England.

Mekies discussed the forensic approach of the FIA's safety department and presented several studies carried out by the FIA's research partner, the Global Institute for Motor Sport Safety. These studies included the single-seater cockpit safety device research and the Formula E seat belt tension measuring device.

Mekies described the feeling of pride he felt while delivering the lecture, which is named after safety pioneer Professor Sid Watkins.

He said: "We are trying every year to contribute to this effort and to try and make sure the sport remains safe. I'm particularly honoured to be here because I think it is one of the best, if not the best examples of paying tribute to Sid Watkins."

F1 world champion Nico Rosberg gave the award to Low

PARALYMPIAN WINS FIRST KEEP FIGHTING AWARD

Paralympic champion Vanessa Low has been presented with the inaugural Keep Fighting Award, which has been established through a charity initiative launched by the family of seven times Formula One world champion Michael Schumacher.

Low lost both of her legs in an accident at the age of 15 but has since gone on to win a number of ParaAthletics titles in long jump and 100m events, including a long jump gold at the 2016 Paralympics in Rio de Janeiro.

As she accepted the award, which was presented by FIA President Jean Todt and 2016 F1 world champion Nico Rosberg, Low said: "I admire the Schumacher family for their courageous step. I am completely behind the values that this award represents and I am very happy to help spread them. I was very surprised on first learning I was the winner, I am very proud I have been selected and I would like to thank them for it."

Speaking on behalf of the Schumacher family, spokesperson Sabine Kehm explained why Low had been chosen as the first winner of the Keep Fighting Award: "[She] embodies and conveys the values that this prize wants to promote: to never give up and; despite setbacks to positively shape the future."

INDIAN STUDENT WINS WATKINS SCHOLARSHIP

Indian student Nikil Abraham has won the 2017 Watkins Scholarship, a funded position in motor sport safety research.

Named after motor sport safety pioneer Professor Sid Watkins, the scholarship offers a one-year position with the Global Institute for Motor Sport Safety, the research partner of the FIA, and is jointly funded by the FIA, FIA Foundation and the Global Institute.

Abraham, who holds a Masters Degree in Automotive Engineering from the FH Aachen University of Applied Sciences, was selected by a panel of experts that consisted of Formula One Managing Director Ross Brawn, German Motor Sport Federation Medical Director Michael Scholz and Global Institute General Manager Research Laurent Mekies.

Abraham said: "I am delighted to win the 2017 Watkins Scholarship and take up this role at the Global Institute. It is going to be a challenging but very interesting year and I look forward to continuing the legacy of Professor Watkins and making a real difference to the world of motor sport safety."

Luc Argand, the Global Institute Chairman, said: "We are pleased to welcome Nikil to the Global Institute as our second Watkins Scholarship recipient. He will be a true asset to our team as we continue our research to improve motor sport safety worldwide."

The inaugural winner of the Watkins Scholarship, Sameer Patel, worked on several high-profile projects in Formula One, World Rally and other FIA championships, and has now taken up a full-time role with the FIA as a research engineer.

Wehrlein missed the first races of 2017

PASCAL WEHRLEIN MISSES F1 RACES AFTER WINTER BACK INJURY

Sauber Formula One driver Pascal Wehrlein missed the 2017 Australian Grand Prix due to concerns over his fitness levels following a back injury he sustained during the winter break.

The German driver will also miss this weekend's Chinese Grand Prix and will be replaced by Antonio Giovinazzi, who stood in for him in Melbourne.

Wehrlein suffered the injury when he crashed towards the end of the Race of Champions event in January. The 22-year-old subsequently missed the first F1 winter test and was forced to pause his winter training regime.

Although he was cleared by the FIA to race in Australia, the training delay left him questioning his ability to complete a race distance in the new-for-2017 F1 cars, which require drivers to have increased physical abilities due to their higher levels of downforce.

Speaking as Sauber confirmed he would not race in China to allow him to rebuild his fitness levels, Wehrlein said: "For me the most important [thing] is that I can train intensively to ensure a 100 per cent performance from my side as soon as possible. I will then be well prepared for my first complete Grand Prix weekend for the Sauber F1 Team."

NEW COORDINATOR FOR ANTI-DOPING INITIATIVE

The FIA's Medical Department has appointed Prisca Mauriello as its new Medical Affairs Coordinator.

Mauriello, who previously worked as a lawyer for ten years in the areas of sports and commercial law, and intellectual property, joined the FIA's Development Department as a Sporting Coordinator in 2016. With a specific focus on anti-doping matters, Mauriello will now joinSandra Silveira Camargo, Head of Medical Affairs, and Magali Louis, Medical Affairs Coordinator, who concentrates on the department's medical programmes.

The FIA's anti-doping programme, Race True, aims to protect clean drivers through testing and education. It also informs and educates driver support personnel and officials on anti-doping, which is considered a priority by the FIA.

A booklet named "Anti-doping Key Facts", which summarises what the drivers and their entourages must know about anti-doping, was launched in 2016 and is now available in seven languages. It is being widely distributed both by the FIA and national governing bodies.

Race True also provides a ten-language online course to go into more depth on the different aspects of anti-doping, including topics such as the prohibited list, therapeutic use exemptions, dietary supplements, doping control process, and disciplinary procedures.

Last year, drivers competing in all FIA World Championships, Formula E and European Formula 3 series received anti-doping group training based on the principles of the Race True programme. This training will be extended to the FIA European Championships this year.


Prisca Mauriello has been appointed Medical Affairs Coordinator

ETHICS AND EXTRICATION – LOOKING BACK ON ICMS

The International Council for Motorsport Sciences held its annual three-day congress on 7-9 December 2016, where a number of medical and safety topics were covered.

These included the role of biomarkers in the diagnosis of concussion by Dr Alain Ptito, how to build bridges in motorsports safety by Dr Matthew Mac Partlin, and an explanation of damage control resuscitation for catastrophic bleeding by Dr Timothy Pohlman, which featured an in-depth analysis of James Hinchcliffe's near fatal IndyCar accident in 2015. Hinchcliffe also stepped up to the stage to talk about his experiences.

AUTO+Medical takes a closer look at three presentations, which covered ethics, fire simulation training and spinal motion during driver extrication procedures.

ETHICAL CONSIDERATIONS FOR MEDICAL DIRECTORS AND TEAM PHYSICIANS

DR STEVE OLVEY

Dr Steve Olvey, Associate Professor of Clinical Neurology and Neurosurgery and Bioethics Consultant for the University of Miami, discussed the ethics that motor sport medical personnel should consider.

He began by outlining examples of the best ethical practices for physicians: "[These are] beneficence, do no harm, confidentiality, and honesty."

Then, using six case studies – from a hypothetical young karting prodigy who has suffered numerous head injuries, to a fictional marshal reporting defective safety barriers – Olvey explained how the ethical considerations for motor sport physicians cover four areas: fairness, integrity, responsibility and respect.

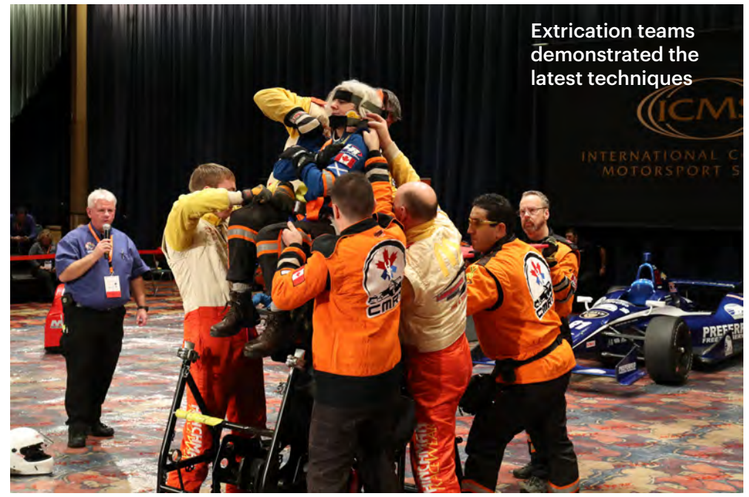
He then covered the problem of dual agency – and the accompanying responsibility problems this creates for medical directors – and examples of preventative ethics. These include arranging local providers to medically cover an event, ensuring the competency of the medical and safety teams, developing a satisfactory mass casualty plan, designating appropriate local hospitals, maintaining accurate medical records, and being alert for extreme environmental and other unexpected all-encompassing issues.

When it comes to medical personnel working for motor sport teams, Olvey explained that it is important to respect the established hierarchy, be aware of favouritism, and to stay loyal to that squad. "What's best for the team is usually what's best for each member of the team," he explained.

Olvey also explained that medical officers should be aware of participants abusing the system, doping amongst the competitors, non-unified reporting to the media, entanglement with a participant's personal issues, and any potential traps placed to cast doubt on the medical systems in place.

"The Medical Director has an obligation to provide for the general well-being of all those involved in the event," he said in summation.

Indycar star James Hinchcliffe praised the work of the medical staff that saved his life



Extrication teams demonstrated the latest techniques

SPINAL MOTION DURING RACE CAR DRIVER EXTRICATION

DR TARA T. AMENSON

Dr Tara Amenson, a Biomedical Technical Consultant at the SEA systems software company, gave a presentation that explained the preliminary results of her study that assessed spinal motion during the process of driver extrication.

The purpose of Amenson's study was to "measure the spinal motion of conscious human subjects with stable spines during simulated extrication, investigate the effect of immobilisation techniques on cervical spine motion, and to investigate the effect of extrication and transfer techniques on spinal motion," she said.

After explaining the existing literature and the practice of immobilising the cervical spine during management of traumatically injured drivers, Amenson described how "neurological injuries can be caused or exacerbated by techniques used during extrication, yet some spinal motion is inevitable [in that process]."

Her study therefore looked at spinal motion limits during the extrication process, and applied instruments to human subjects during practice rescue sessions.

During the study, which involved a 5ft7inch, 160lbs adult male with no history of spinal pain or trauma being fitted with a string of six tri-axial accelerometers and tilt sensors, data was collected at 20Hz with sensors using associated software. The data was recorded as tilt angles relative to gravity and regional ROM, which is the relative motion between adjacent distal and proximal sensors. "Accuracy of the sensor string has previously been investigated within high precision, such as yaw, pitch, and roll movements," said Amenson.

Amenson's report suggested that one sensor, fitted on the C3 vertebra during the study, measured movement of between four and minus four degrees during the time period of 700 and 1600 seconds during a practice extrication exercise.

BENEFITS OF DIGITAL FIRE SIMULATORS IN MOTOR SPORT

FRANK HULSCHOFF

Frank Hulschoff, the marketing director of the Bullex Haagen fire fighting training company, delivered his presentation on the benefits of digital fire simulation products for teaching motor sport safety crews and team members.

Bullex Haagen provides fire safety training tools – such as advanced live fire set-ups, smart props and digital fires – and Hulschoff explained that the company's interests are driven to "bring people home safe".

To apply its fire simulation technology to motor sport, Bullex Haagen has built a replica Formula One car prop, which it has dubbed the 'Sapeurs Pompiers de Monaco'. The model, which is 4.47m long and 1.7m wide, is fitted with an engine fire, cockpit fire, smoke generator, extinguisher filler, remote control operating system, and a fire resistant training manikin.

Hulschoff also described how the pit lane area of motor sport events presents a distinct danger of fire due to the presence of refueling equipment and other associated kit, as well as the large number of people working in a confined area. He explained that one of the benefits of fire simulation software is that these personnel can be trained how to safely intervene if a blaze breaks out.

"In the pit lane is arguably where there is the highest chance of a fire related incident," he said.

"This means the persons who are first to respond to a fire are usually not trained fire fighters but team members such as mechanics. Training methods until now needed real fire and this is far too risky in the pit environment."

AUTO+MEDICAL FEATURES

FEATURES

GETTING PHYSICAL

With increased speeds come higher G-forces, so F1 drivers have been working with doctors and trainers to ensure they are physically up for the fight in the 2017 season

Formula One cars are fast, but in 2017, for the first time in a generation, they have been built to go faster through corners. This has and will have a major effect on the drivers throughout the season as they face some daunting physical challenges ahead.

The cars are up to 40km/h quicker through high-speed corners as a result of the increased levels of downforce created by the new chassis regulations and the bigger tyres the championship has introduced. This means the drivers have significantly higher G-forces acting upon them as they race through F1's fastest corners.

Any increase in cornering speed also adds to the potential for the drivers to get hurt if they have not sufficiently trained their neck and shoulder muscles to cope with higher G-forces.

According to F1 Medical Rescue Coordinator, Dr Ian Roberts: "Good muscle bulk and tone can reduce injury severity to the joints and bones that they serve, but if the forces are sufficient, injury can still result. Weak muscles in the neck, for example, support the head poorly as the G-forces act upon it, and consequently soft tissue and ligaments can be torn."

When the updates to the F1 regulations were announced in 2016, it soon became apparent to the sports medicine personnel and trainers employed by the teams and drivers that existing fitness regimes would have to be adapted.

"We knew that cornering speeds would increase substantially and would make the cars more physical to drive than they had been for over a decade," says Hintsa Performance Medical and Sports Performance Director, Dr Luke Bennett, who is the F1 team doctor for both Mercedes and McLaren squads. "So we

Carlos Sainz doubled the length of his workouts ahead of 2017

"THE DRIVERS TRIED TO MAXIMISE NEURAL AND STRENGTH ADAPTATIONS WITHOUT INDUCING MUSCULAR HYPERTROPHY"

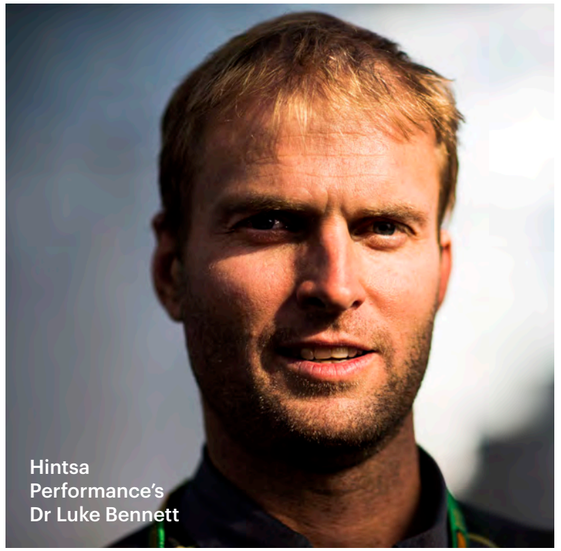
saw a substantial increase in commitment from all of our drivers and coaches this winter based on the assumption that the cars would be much more physical to drive."

The push to increase fitness levels for 2017 – with greater focus on head and neck strength – led to F1 drivers starting their winter training earlier than they had done in previous years. They used to focus on keeping their weight to a minimum, a consideration that they still had to bear in mind for this season, as the new chassis regulations have not made the cars any lighter. But strengthening was the key consideration this year.

"The specific programmes required vary considerably with the baseline weight, interests, strengths and weaknesses of each driver," explains Bennett. "But it's fair to say that they all took significantly less time off in December and added much more dedicated time in the gym this winter."

To increase strength, instead of focusing on long sessions of cycling or running to work on their cardiovascular systems as they did in the past, the drivers have had to balance those pursuits with the need to increase the amount of weight training they did to build stronger muscles in the neck and shoulders.

"Before you were designing your training programme to not gain any weight," explains Haas F1's new driver Kevin Magnussen. "Now we've relaxed that a little bit and we're able



Hintsa Performance's Dr Luke Bennett

to train harder with more strength-focused training rather than just long cardio sessions."

Toro Rosso's Carlos Sainz revealed that his winter fitness regime doubled in length to incorporate all of the additional strength exercises the drivers put in before the start of pre-season testing.

"Our fitness levels of 2016 won't be any good for this year, so for that reason we needed to step it up even more," he says. "Instead of sessions of 50 minutes, which is normal, mine were between 1.5 and two hours – the length of a GP – and we were working at around 180-190bpm heart rate. It also included boxing and cardio work, it was relentless and we never stopped working during the entire session. It was full-on physically."

Sainz also explains the ways he trained his neck to cope with the higher G-force levels. These ranged from specific weight sessions in the gym to driving a go-kart with a weighted helmet to simulate the new conditions on the track.

"We had two ways of training the neck," he explains. "The first was with weights in the gym, which helped prepare for the G-forces we'll have to face in the car. The second was with a specific method when karting. These weights made the helmet around 1.5-2kg heavier than normal, which corresponds to the kind of extra weight the G-forces feel in F1. This, together with other specialised exercises, gave the neck muscles a very good workout."

But as is the case in so many areas of F1, it was not just about improving one specific area. The drivers also built up strength in other areas of their bodies to improve their overall performance.

"Core abdominal, back and pelvic muscle strength is always of huge benefit in open-cockpit motor sport categories," says Bennett. "Together with building a better cardiovascular endurance base, these have been additional priorities. Explosive braking forces are demanding, so leg strength is also a more focussed adjunct to this core stability."

Less time off and more fitness training might not have sounded appealing to a young F1 driver, but Sainz's Toro Rosso teammate Daniil Kvyat saw it differently: the better prepared a driver was for the new season, the more they would enjoy driving the new cars over the course of the year.

"I'd rather be training than partying," he says, "as the end result is I get to drive an F1 car. So it's always a pleasure to work towards good results. When you know you have done your preparation work as well as possible, then you can approach everything in a calm state of mind."

EVERY LITTLE HELPS

The balance the drivers faced of adding as much strength as possible whilst minimising

> **"SEVERAL DRIVERS HAVE HAD TO MODIFY OR REDUCE THEIR INTAKE OF LARGE FISH IN THE CONTEXT OF AN OTHERWISE VERY HEALTHY DIET"**

the weight that accompanies muscle gain stems from a constant source of debate between their trainers and race engineers, who want to keep the overall weight of car and driver to a minimum. As a result the drivers tried to maximise neural and strength adaptations without inducing muscular hypertrophy.

Some of the ways they achieved the desired balance included completing lower numbers of repetitions with heavier weights, giving increased attention to more technical measures like plyometric training, having longer recovery intervals and undertaking more explosive lifting when working out.

Strict, healthy diets also play a key role in helping drivers to keep their weight down, a focus that became particularly important in F1 when the V6 turbo regulations were first introduced for the 2014 season and the overall weight of the cars increased significantly. While eating balanced and nutritious foodstuffs is not a new revelation for professional athletes, there have been recent discoveries about certain foods that mean they are no longer suitable for drivers to consume in large quantities.

"Weight minimisation is an issue for many F1 drivers and there is an unsurprising focus on eating whole foods of high nutritional value, eliminating junk carbohydrates and balancing macronutrient intake appropriate to their training needs," says Bennett. "One particular contemporary issue has been the requirement to monitor heavy metal ingestion - several drivers have had to modify or reduce their intake of large fish in the context of an otherwise very healthy diet."

STAYING IN SHAPE COME RAIN OR SHINE

Health and fitness concerns were not just a pre-season problem for the F1 drivers heading into the 2017 season, as the demanding 20-race calendar requires a lot of effort from them to stay at their maximum performance capabilities.

Incorporating the strict training regimes and diets into a driver's busy schedule is a real art for F1 doctors and trainers every season. As well as the long calendar, this is also because each racer has their own attention span and interests that need to be accounted for when it comes to designing a wellbeing regimen. Even during the off-season, it can be difficult for them to manage a week of consistent, uninterrupted physical training due to the number of commitments placed on them by their teams, sponsors and outside demands.

"Once the first pre-season test begins in February, the coaches and drivers more or less enter a maintenance phase with respect to training, with perhaps a handful of further opportunities to top up fitness through the year,' explains Bennett. "The late season fly-away schedule from mid-September is both brutal and decisive for championship outcomes, so the mandatory summer shutdown each August can be a fine balance

Sainz used a weighted helmet during go-kart training over the winter

Higher levels of downforce from new aero parts have increased speeds and G-forces

between prioritising mental recovery with a good holiday, and squeezing in a few more physical training sessions."

The current F1 calendar includes back-to-back events in Singapore and Malaysia, which are regularly described as the championship's toughest races due to their hot and humid climates. The higher G-force levels will make things even tougher for the drivers during these events in 2017, but their fitness advisors have worked out ways to help them adapt to the heat.

"Cooling and hydration protocols on race weekends are the mainstay of managing these conditions," says Bennett. "But for specific drivers and where the schedule allows, we may acclimatise in the weeks beforehand using a period of training in Asia or a dedicated heat chamber closer to home in Europe."

STRONG DRIVERS, STRONG CARS

Although the hotter races on the F1 calendar require special preparation, Dr Ian Roberts reckons the increased cornering speeds could lead to a driver suffering a sudden loss in performance capabilities at any race if they have not sufficiently kept their strength high throughout the year.

"For racing, any increased G-force with higher cornering speeds will affect the whole body, but the extra forces placed on the head require good strength and endurance from the neck and shoulder muscles," he explains. "Rapid driver fatigue, countered by good preparation, can certainly be an issue over the duration of the race."

When it comes to potential crashes, however, the risk of drivers getting hurt in crashes has not been increased with the new cars, according to Roberts.

"Deceleration injury, plainly, is not simply a result of increased car speeds but of uncontrolled deceleration," says Roberts. "Rapid deceleration, its vector and rotation are all very important in the mechanism of injury, and that is why some apparently more trivial impacts can be significant. As always, good car engineering and track safety measures make a significant difference to the outcome."

THE PAY-OFF

From the very first test of 2017, the drivers discovered how physically challenging this season will be. Mercedes F1 star Lewis Hamilton says: "It doesn't matter how fit you are and how hard you trained, you get in that car and it beats the crap out of you. It just does, there's just no simulation for it. So whether you feel it in the neck – there'll be a muscle you didn't even know you had, deep down under your rib cage, and you're like 'what the hell?' – through those testing days you figure those weak areas out."

The British driver, who uses the demands of cross-country skiing to boost his cardiovascular and physical fitness levels, described the sensations of driving the new faster F1 cars for the first time. "I definitely put my body to the test. It was good to feel the wider, beefier car. You've got to drive it a bit differently, [but] it's so much better than last year's cars. The G-Forces are definitely higher. It's faster, more physical, it's a beast."

The new cars were designed to be significantly faster, and as the season develops the current crop of F1 drivers will be hoping the hard work of their winter training will pay off by allowing them to produce consistent performances throughout the year, despite the greater demands the higher G-forces are placing on their bodies.

Magnussen swapped long cardio sessions for strength training

MOST DEMANDING F1 RACES

SINGAPORE GP
F1's night race takes place at the Marina Bay circuit, which has the highest number of corners of any F1 track (23). It also has the second highest average monthly temperature.

MALAYSIA GP
The race at the Sepang circuit takes place in sweltering conditions, with on track temperatures hitting 56 degrees in 2016. It is also the longest race at 310.4km.

MEXICO GP
The Mexican race takes place at 2,229m above sea level - the highest altitude all season - and as a result the cars also record the fastest speeds (372.5km/h) at any track on the F1 schedule.

DR BRENT MAY

Chief Medical Officer, Australian Grand Prix
MBBS, FANZCA, MSc (Trauma) Specialist Anaesthetist and Prehospital Physician

Dr Brent May is the Chief Medical Officer for the Australian Grand Prix. Ahead of the 2017 event he tells AUTO+Medical about the challenges of running the medical team at what has become Formula One's traditional season opener and how he would improve motor sport medicine.

AUTO+Medical: How did you first get involved in motor sport?
Brent May: I have always loved watching motor sport and even met my wife at a race meeting, but not as a patient. My first experience was at Phillip Island after a friend invited me down to the track as a junior doctor. I arrived at the track and met an amazing group of people who I am still friends with to this day.

At that event, a V8 Supercar crashed no more than 30 metres from us at high speed. We responded straight away and from that moment on I was hooked. I am still with the same volunteer medical team, Team Medical Australia, more than 10 years later.

A+M: How did you become CMO of the Australian Grand Prix?
BM: To be honest, it was like any other job interview with a CV, panel interviews and a tense wait. The Confederation of Australian Motor Sport (CAMS) has a pretty formal and open approach to this stuff to make sure it gets the best candidates. I was extremely pleased to receive the call confirming that I was successful.

> **"I HAVE ALWAYS LOVED WATCHING MOTOR SPORT AND I EVEN MET MY WIFE AT A RACE MEETING, BUT NOT AS A PATIENT"**

A+M: What does your work as CMO involve in the period leading up to the race?
BM: I think the hardest thing about being a CMO is losing most of the clinical and on-track work and moving to more administrative tasks and logistics. All the lead-up to the race is recruitment, administration and making sure that the service is consistent with the regulations.

I also spend significant time building redundancy into our system and organising all the equipment and resources. We run a full day training simulation on the day prior to the event to make sure we have consistency despite the varied backgrounds of everyone involved.

A+M: What is your role during an actual F1 race weekend?
BM: Like most CMO's for F1, my role is oversight and governance. I sit in race control with the FIA medical delegate and my medical communicator. We make sure the on-track responses are appropriate – applying my experience in motor sport and making risk assessments based on that. I also make decisions on the fitness of a driver to compete in conjunction with the FIA medical delegate.

A+M: What medical and safety facilities do you use during the Australian Grand Prix?
BM: We have a temporary circuit at Albert Park in Melbourne. We run a team that includes five medical cars and six ambulances. Due to the proximity of the track to a Major Trauma Centre – 90 seconds from gate to door – we have special dispensation to work without a medical helicopter.

Our medical centre is also geared much more to orthopaedic and minor injuries but still has resources and personnel to deal with any serious trauma or medical condition.

A+M: Does the temporary nature of the Albert Park paddock influence the set-up of the medical facilities?
BM: We have a specific area that the medical centre is located in each year. I think this is important because the medical centre is easily accessible from the track and to external roads. Plus all drivers and officials know where it is, as do the international travellers. This reduces the risk of errors in finding the medical centre by those looking for it and also means that we minimise transport times.

The Albert Park race takes place on a temporary circuit

Alonso's accident at the 2016 Australian Grand Prix was the biggest crash May has witnessed

A+M: The 2017 Australian Grand Prix was the first race with the new, higher-speed F1 cars – how did you prepare for that?
BM: We are very used to being the first Grand Prix of the season and have experienced minor and major changes to the cars in the past. The introduction of the Kinetic Energy Recovery Systems in 2009 and then the 2014-spec ERS, as well as changes in engines, have meant that we spend a lot of time researching the cars and educating our team prior to the event.

I don't think the increase in speed will place any significant pressure on our medical service although we may see some more incidents. We are prepared for anything that happens but the Formula One cars are extremely safe as we saw with Fernando Alonso's crash last year. I am awaiting the possible introduction of the Halo system and the issues that may present for our extrication teams in 2018.

A+M: Can you explain how the medical facilities for spectators are arranged in Albert Park?
BM: We have both a first aid service and ambulance response service dedicated to the spectators. Given the proximity of the circuit to Melbourne's Alfred Hospital, any injury or illness of any significance is rapidly transported there.

A+M: Can you describe the biggest challenge you have faced as a motor sport doctor?
BM: A death at the circuit is always the hardest to deal with. The memory stays with you forever and you always think about the causes, safety aspects, management and what could have been done to prevent the outcome. Fortunately, fatalities are rare in Australian motor sport but the few I have been involved with still stay with me.

A+M: What has been your greatest achievement in motor sport medicine?
BM: My recent award as the FIA Doctor of the Season was an amazing honour to receive. It was wonderful to be recognised for the work I do for CAMS as well as in my role as CMO for Karting Australia and Motorcycling Australia.

A+M: Can you give any examples of incidents you have responded to during your time as a motor sport doctor?
BM: With almost 20 weekends of motor sport a year over more than 10 years, there are many. From high-speed rollovers, start line incidents with multiple wrecks to heavy impacts into the wall and trapped drivers.

I have also seen some strange accidents including riders trapped in motorcycles and drivers trapped in karts. The biggest incident in recent memory was watching Alonso walk away from his crash at the 2016 Australian Grand Prix. It just showed me that you need to be prepared for everything. Medical teams need standardised communication and operating procedures so that when 'it' hits the fan, you can rely on your training as a team.

A+M: What is the most rewarding part of your work in motor sport medicine?
BM: It used to be good outcomes from each incident I attended, but these days, it is the education and training I do. Travelling internationally is very rewarding and reinforced by the emails I receive from those I have shared knowledge with.

Locally, it is sitting on committees and commissions to improve standards and medical responses in motor sports across CAMS, Motorcycling Australia and Karting Australia.

A+M: In what ways would you improve motor sport medicine?
BM: I think education and research are the keys to improving motor sport medicine. I have been fortunate to travel internationally and help spread contemporary, relevant and evidence-based education programmes to the motor sport community. I think the time has come when we can use technology to make these programs more pervasive so that many can benefit.

With regard to research, we sorely need a minimum recommended data set that can be easily collected in each country. Collaboration between organisations using the same data sets allows for rapid comparison and much bigger numbers to get meaningful results. The use of apps and technology will greatly assist these programmes.

May was given the 2016 FIA Doctor of the Season award

PREDICTING THE UNPREDICTABLE

Simulation and data analysis programmes are key tools for modern circuit designers. AUTO+Medical examines how they are used to create exciting and safe motor racing tracks.

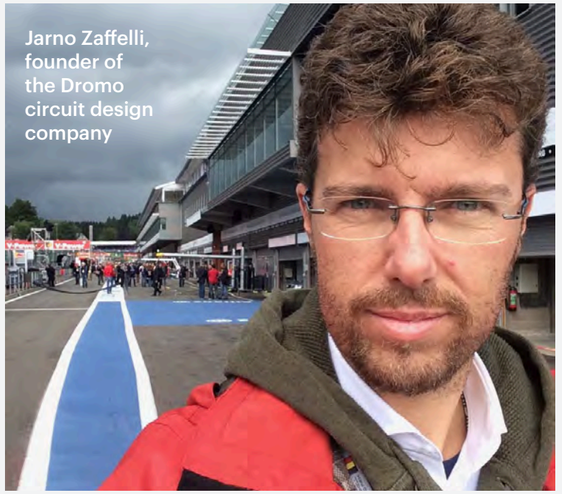
The 2016 FIA WTCC Race of Argentina at the Termas de Rio Hondo track, built using prediction tools

Motor sport is dangerous, and crashes have always been part of the thrill of the competition. But technology is now capable of taking the unpredictable elements of racing and looking for patterns in the chaos with the aim of improving circuit design, as well as the positioning of safety staff and equipment. Crashing just got a little less random.

When it comes to designing circuits or improving existing venues, simulation and data analysis software have become vital. Jarno Zaffelli, the founder of the Dromo circuit design company, spent 11 years gathering data – crash figures, on-track events, and general circuit statistics – that he converted into a programme that he believed would aid circuit design.

"I always aim to do what is possible to improve circuits," says Zaffelli. "That doesn't mean to take away crashes, incidents, and clashes, but to try to take away the predictable ones and leave the racers to enjoy the tracks for our own enjoyment. The FIA is working on safety improvements and regulations, promoters work on race formats and media appeal, and I'm helping to bring the objective tools I use to support my experience in race track design."

After a few months of research and development, Zaffelli produced Dromo's first prediction model, which used artificial intelligence algorithms based on the data he had collected during his track study. The first instance of the crash calculation software used the geometry data, crash statistics, and images captured on the video feeds from the CCTV cameras installed around the courses.



Jarno Zaffelli, founder of the Dromo circuit design company

"Using a simple classification we determined the classes for the programme," he explains. "Some are predictable and we focused on collecting these by examining, understanding and looking for evidence. Everywhere, we looked at a wide spectrum to find possible correlations to build a model robust enough to be deployed. Statistics cannot be used to predict the future, but they can be used to try to understand what happened in the past, and react."

SIMULATION SAFETY

Another important tool for circuit designers is simulation software. For Clive Bowen, founder and director of the Apex circuit design, it is an essential part of the design process as it can predict potential hazards and accident zones.

Apex's simulation software takes raw data from the on-board recorders of various categories – from touring cars to FIA Formula 3 to Formula One – and creates a 'best fit' model for new corners and runoff areas.

"We have developed that simulator with new data and better analysis, so now we can use the criteria for different media along that trajectory whether it be grass, gravel or asphalt, and we have an idea of speed decay as you cross those different surfaces," says Bowen.

Clive Bowen, founder of Apex circuit design

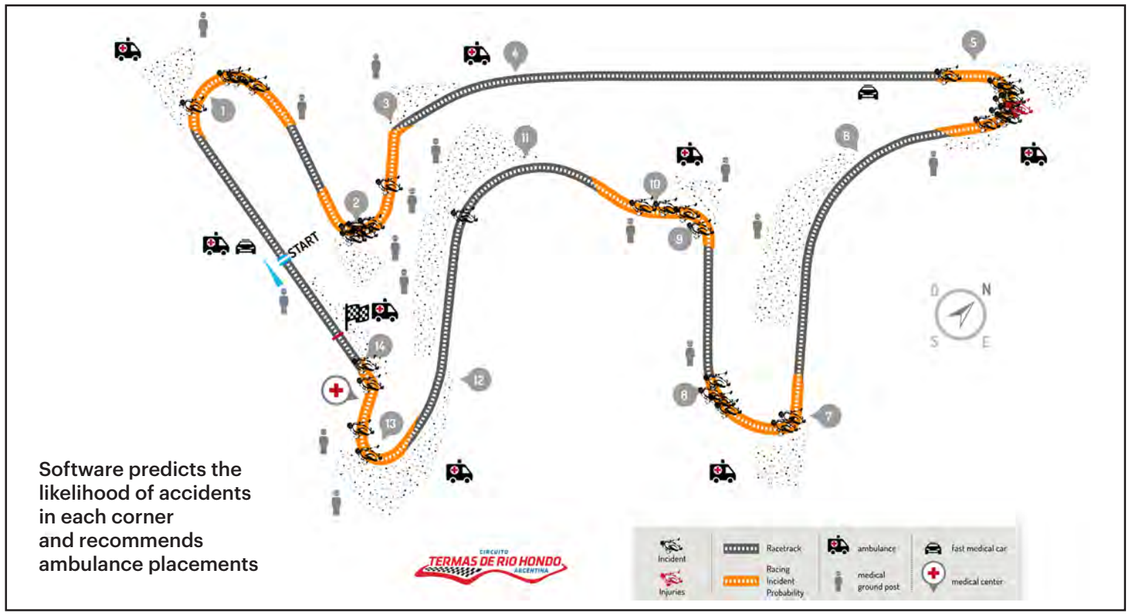
Simulation software also enables circuit designers to understand the angle of any impacts that may occur at corners, which they can adapt to make sure the crash occurs at an angle of 30 degrees or less to try and ensure that the accident is less severe.

"You can mitigate risk and you can design the corners so that the impacts are going to be 30 degrees or less, which is a known angle where if you are 30 degrees or less it will be a glancing blow rather than a sudden stop," explains Bowen. "So what you can do is deflect the trajectory of the vehicle, and it then dissipates its speed on a different trajectory."

CRASH PREPARATION

Zafelli relies more on a crash prediction model for his track designs. In 2012, he worked on an overhaul of the Termas de Rio Hondo circuit in Argentina, which had first opened in 2007.

The track was rebuilt with Dromo's safety



Software predicts the likelihood of accidents in each corner and recommends ambulance placements

recommendations incorporated into the new layout, which brought it up to the top level of safety standards required by the governing bodies of international automobile and motorcycle racing.

"We designed the new track on the basis of the existing one, to receive FIA Grade 1 and FIM Grade A homologation, so all the track and runoffs were designed for both world championship events," explains Zaffelli.

At that stage, Dromo's software – the first "public prediction algorithm available" according to Zaffelli – was tuned for motor bike racing and one of the company's engineers had individually analysed all 865 crashes from the 2013 Moto GP championship. From that study, Dromo produced a report marking the location of the incidents and logging any injuries sustained by riders during those crashes.

Ahead of the 2014 Argentina motorcycle Grand Prix, the first premier class motor bike race event to be held at the Termas de Rio Hondo circuit since it had been rebuilt, Dromo showed its crash prediction software to FIM's then chief medical officer, Dr Michele Macchiagodena. Working together they planned where to situate rescue and medical personnel based on the areas of the track where accidents were likely to occur according to the programme.

"We discussed the results of the model," says Zaffelli, "and we began to think about how to deploy the medical teams around the track. Macchiagodena's idea was to put the rescue teams and ambulances where the model was indicating the most likely number of crashes, coupled with their magnitude. Nobody had experience on the track, as it was brand new, and this was the only information available in addition to his own career experience."

The start of the 2014 Moto GP Argentina Grand Prix at the Termas de Rio Hondo

"THE PROCESS OF CIRCUIT DESIGN IS AS MUCH ART AS IT IS SCIENCE, INNOVATION REQUIRES ORIGINAL THOUGHT"

After the race, Dromo compared its crash prediction software with the events that happened at the track that weekend. Across the three days of on-track action, 36 crashes occurred with 93 per cent of them happening in an area of the circuit that the programme had determined that 90 per cent would occur. There was a single injury, which happened at the track's Turn 5, where an ambulance was positioned.

ALTERNATIVES TO ALGORITHMS

But relying solely on crash prediction software is not always an approach favoured by all circuit designers. For Bowen, when it comes to producing a new track it is important to combine a scientific approach with creativity.

"The process of circuit design is as much art as it is science," he says. "It is a design process where innovation requires original thought. If you were to apply an algorithm that designs a track, you'll end up with the same thing coming out each time, which is not going to challenge the drivers or impress the visitors or the spectators and will ultimately make the whole process anodyne. You want to have some kind of quirkiness to create an identity for a different location compared to another."

Another consideration is the landscape of that location, which is usually incorporated into the design of the circuit, particularly with

street circuits where the presence of buildings and walls heavily influences the layout.

"You identify what you can fit within your site and you seek to achieve a particular criteria depending on whether you're aiming for something that is like a Formula One track or the other end of the scale where you're looking at club racing," says Bowen, who worked on the Dubai Autodrome and the Kuala Lumpur street circuit. "You also need to accommodate the FIA's guidelines and the various appendices to the sporting code, so we've got some pretty good standards to meet."

"YOU ALSO NEED TO ACCOMMODATE THE FIA'S GUIDELINES, SO WE'VE GOT SOME PRETTY GOOD STANDARDS TO MEET"

Visibilty is crucial for motor sport safety workers

VISIBILITY AND TRACK ACCESS

Another aspect of track design is visibility analysis, which is an important safety consideration for circuit designers. Designers need to make sure safety staff can clearly see each other around the track and ensure the drivers have a clear view of the marshals' posts so they are forewarned of any upcoming danger.

The topography of the venue and other elements of proposed circuit infrastructure are all factored into the simulation to ensure they do not impede visibility.

"We have a means by which we can identify what is visible and what is not to the eyeball," says Bowen. "So if we locate a marshal post, we then run, almost like a radar sweep, a simulation that we've established that looks at the 3D model we've created and takes into consideration barrier locations, and, if you've got them, lighting mast locations. We always try to ensure that before we've even asked a circuit inspector that you can see from one marshal post upstream to the next, and downstream to the previous one. And we ensure that the view to the circuit is unencumbered for that section between marshal posts because that by definition means if you can see it, it can see you. So therefore the racing driver is going to be able to see the marshals posts and therefore the flag being waved."

While event and championship chief medical officers often work with circuit designers to plan the location of medical crews at race events, another important consideration when building a new track is access to the course for recovery and other safety vehicles.

DROMO'S CRASH PREDICTION MODEL CLASSIFICATION

EVENT TYPE	CAR	BIKES
Total loss of control	Predictable	Predictable
Water crossing	Predictable	Predictable
Spin (High side)	Predictable	Predictable
Understeer (Low side)	Predictable	Predictable
Mechanical failure	Unpredictable	Unpredictable
Aerodynamic failure	Unpredictable	Unpredictable
Electronic failure	Unpredictable	Unpredictable
Partial loss of control	Part. Predictable	Rare
Contact between competitors	Unpredictable	Unpredictable

These are usually placed at the juxtaposition of where the straight boundaries of the circuits meet the side on areas. A corner such as Silverstone's Copse would have a 'snatch gap' facing the barrier so a recovery vehicle could quickly move to pick a stranded car and then reverse off.

"Logically you would have an access point at that deepest point in a corner runoff area, and depending on the size of the circuit and the length of the arc and the likelihood of an incident, you would have at least one, possibly two, more access points to that runoff area," says Bowen. "These may not necessarily have a recovery vehicle parked there but may allow one parked elsewhere to be able to manoeuvre around and go through the other access gap."

The use of simulation software and data analysis has become more and more commonplace in many areas of motor sport. To circuit designers, these programmes are vital tools for creating and improving racing venues around the world.


Safety barriers and track access points are major factors for circuit designers

Silverstone's Copse corner (here in 2015) has a 'snatch gap' for safety vehicles

INSIDE RALLY SWEDEN'S MEDICAL OPERATION

AUTO+Medical examines the medical equipment and facilities used at Rally Sweden 2017

Providing medical coverage for a World Rally Championship event that covers over 14,000km is no easy task. Combine that with a setting in a snow-packed forest in the middle of a Scandinavian winter and it is clear that Rally Sweden requires a unique approach.

To keep World Rally Championship competitors and spectators safe, Rally Sweden employs 11 doctors, one paramedic, one anaesthesiology nurse, and two fire fighters working across eight medical intervention cars.

The event has a main medical centre based at the rally service park, which is manned by one doctor working alone or with a nurse. The centre also has an ambulance waiting on standby ready to transport patients to the designated emergency hospital, which is just five minutes away from the service park.

As well as taking care of the drivers and team staff competing in the event, Rally Sweden's medical team is responsible for helping the spectators that come to watch the cars. They are supported by a team of Red Cross workers that are located near the event's specific viewing areas.

AUTO+Medical takes a detailed look at some of the other facilities used by the Rally Sweden medical team.

MEDICAL INTERVENTION CARS

All eight of Rally Sweden's medical intervention cars are equipped especially for the event according to the FIA's regulations for the WRC. There is a medical vehicle stationed at the starting point on every stage but for the longer runs a second car is positioned at an intermediate point, which is to ensure that there is no more than 10 minutes transport time to the scene of an accident. Ahead of the rally, the event's CMO is required to travel with the Safety Officer or Clerk of the Course to establish the correct positions for the medical vehicles along the route.

EQUIPMENT
Each medical intervention car is equipped with a full set of airway stabilisation equipment, specific drugs, neck stabilisation kit and IV fluids. However, IV fluids, which are usually provided to seriously injured patients to help them avoid hypothermia, may freeze in cold environments. Each car is also required to have two 4kg fire extinguishers, a warning siren, and a kit of basic rescue equipment determined by the CMO in collaboration with the event's chief scrutineer. The cars must have suitable communications equipment to maintain contact with Rally HQ, which is where the CMO is stationed to co-ordinate the response to an incident.

AMBULANCE
Alongside the medical intervention cars, an ambulance is stationed at the start of each stage, as well as in the service park. The vehicle is equipped for treating vital distress symptoms, whether neurological, respiratory or circulatory, and the crew is comprised of a driver, a doctor proficient in resuscitation or a paramedic, who may also be the driver, according to the FIA's WRC regulations. Along with the rest of the medical team stationed around the course, ambulance staff members are required to communicate with the CMO either through the general radio network or through a dedicated network radio channel.

STAGE START
Around 100,000 spectators attended the four days of the 2017 Rally Sweden, and although many issues that arise from the crowds are dealt with by the Red Cross staff, the event's fully medically equipped rescue helicopter, which has a doctor stationed on-board, is available to provide assistance in case of a serious incident. "This year three people got injured in a snowmobile accident on their way to the stage," explains Dr Maria Lannerås, the event's CMO. "Two of them had fractures to the femur and one had an arm fracture. In a separate incident, one spectator got treated for a severe allergic reaction."

STUDDED TYRES
The cold climate of Rally Sweden, and the snow and ice the drivers have to compete on, also presents a challenge for the medical intervention teams and their vehicles. Each medical car is a dedicated all-terrain vehicle and is fitted with distinct winter tyres. This means each tyre has special studs attached to provide extra grip, which is an essential requirement for crews responding to an accident on icy roads. "All of Rally Sweden's medical response teams are mobile rescue units that are well trained for extrication and medical first aid," explains CMO Dr Maria Lannerås.

THE ROAD BACK:

KAZUKI NAKAJIMA

The Toyota World Endurance Championship driver looks back at his high-speed crash at Spa in 2015, his rapid recovery from injury and return to racing

During the opening practice session for the 2015 World Endurance Championship event at Spa-Francorchamps, Toyota's Kazuki Nakajima slammed into the back of an Audi car being driven by Oliver Jarvis after being unsighted in heavy spray caused by wet weather. The Japanese racer immediately felt pain in his back that was quickly diagnosed as a broken vertebra. Despite being told the injury would take three months to heal, Nakajima returned to race at the Le Mans 24 Hours just six weeks after his accident. He spoke to AUTO+Medical about the incident and his recovery.

AUTO+Medical: How did the crash occur?
Kazuki Nakajima: It happened in the opening practice session and the conditions were quite wet. I was going along the straight after Eau Rouge and was almost next to one of the Audi cars. Because he was in front of me I went to the side of him to avoid the water screen and I think there were a couple of LMP2 cars in front of us and the other Audi, car eight [driven by Jarvis] was there too.

I think car eight was probably trying to let its sister car by so he was not going at full speed. But I couldn't see him because of the water screen and I basically just hit him from right behind without noticing he was there until I hit him. I couldn't brake or even get prepared for the impact.

A+M: Were you aware that you had hurt your back immediately?
KN: I had a big crash and straightaway I could feel the back pain. The car was not in a good enough condition to drive back to the pits so I just coasted down to the next corner and I stopped there. Because I felt the pain in my back I thought I should stay in the car until the marshals came to me.

A+M: What did they do when they reached you?
KN: As part of the normal procedure they asked me if I was ok and I told them that I had back pain. Then they just followed the normal extrication procedure, which was done well – I didn't suffer from any additional pain at all from that at least – and then I was put in an ambulance and went to the circuit's medical centre. Then I went straight to the hospital after that.

A+M: What happened at the hospital?
KN: First I was given a bit of medication to reduce the pain, then I went for a CT scan and might have had an X-ray as well – I don't remember exactly. They found the damage I had sustained on the vertebra and I had to stay there for a week or so.

A+M: What did the doctors tell you about your injuries and recovery time?
KN: Initially they told me that I had damaged the vertebra and it would take maybe three

Nakajima returned to action just six weeks after his crash at Spa.

months to recover. They basically told me I had to stay still, as the damage was not too bad so their recommendation was to keep it like that for three months and then they said it would be fine.

A+M: But didn't you come back after just six weeks to race at Le Mans?
KN: Yes, because I had Le Mans coming in six weeks, three months was a bit too long for me. Thanks to our team doctor, he knew another doctor who could do a cementoplasty procedure – where they put material into the bone and this can stick the bone together straightaway.

So I went for the operation, but of course I had to think about it because with an operation there is always a bit of a risk. But for me to race in Le Mans was the number one priority so in the end we decided to go for it at a hospital in Nice in France. One week after the crash I moved out from the hospital in Belgium and went to the hospital in France. Then after being there for two or three days I underwent the operation.

A+M: So what was your recovery process between the operation and racing at Le Mans?
KN: I left the hospital the day after the operation, which was already quite impressive. Then I went to Italy to stay with our team physio and team trainer and there I did quite a lot of rehabilitation processes. This was mainly training together with those guys and I also went to a rehabilitation place for a week. After that I went to a team camp together with my teammates for another week. All of these processes helped me to recover quickly from the operation.

A+M: What happened when you got to Le Mans?
KN: Before driving I had to see a doctor and they checked me. I also had to give them an X-ray photo before driving to show them that the bone was ok. So they checked me and gave me a go, but of course I had to test for

Nakajima was unsighted by the spray kicked up by other cars

myself and for the team to check that I could drive normally. So we did all of those procedures on the Le Mans test day.

A+M: What did it feel like when you got back in the car for the first time?
KN: Initially it was kind of strange; maybe a little bit of a scary feeling, but mostly it was excitement. It was a mixed feeling but soon afterwards I could see that I could drive normally and without pain. After two or three laps I started to get the rhythm back and I felt quite relieved after that.

A+M: Did you have any problems from the injury during the 24-hour race?
KN: Not really. Of course because of the injury I think I had not only damaged the vertebra but also the muscles around it.

Compared to normal or compared to now it was a little bit more difficult – my back was getting tired more easily. But apart from that everything was ok and I managed to finish Le Mans [in eighth place] without a big issue.

A+M: So what happened after Le Mans? Did you have to do more rehabilitation?
KN: Not really because after that I was concentrating more on training rather than rehabilitation to get the muscles around the vertebra back to normal. So I was training more than I would usually have done but apart from that I didn't do anything special.

I had the X-ray checked one year after the crash just to make sure that it was still fine, and it was completely fine. All those muscle issues went away three or four months later so after that I was completely back in shape.

A+M: Was this the first injury that you had suffered in your career?
KN: Yes, it was the first big injury. Of course there was some small ones or maybe I had a bit of pain on the odd occasion, but this was the first proper injury in my career.

A+M: How would you rate the medical care given to you at Spa and later in hospital?
KN: It was good because it was all clear to me what they were trying to do, so the communication between me and all the marshals and doctors was clear all the time. When I understood the injury I was a little bit anxious but all the explanations I received and the result was clear, so it was quite good.

A+M: Is there anything that motor sport medics can learn from your situation?
KN: It's difficult to say because there were no mistakes and everything went quite well. The only lesson I can say is that all the preparation they are doing was quite useful in the end as they did it correctly and in a good way. So I just appreciate that very much.

A+M: What advice would you give to other drivers when it comes to recovering from an injury?
KN: I think every driver has their own priorities – taking part in some race or whatever. So they just need to think about their own priorities and do their best to recover.

I think I was lucky to recover quickly and without any after effects and I could race in Le Mans without any problems. But after the shunt I think I was ready to accept what happened to me and then think about what to do afterwards. It was a good lesson for me and I believe it can be a good one for other drivers too.

AUTO+MEDICAL SCIENCE

SCIENCE

ON-SCENE TREATMENT OF SPINAL INJURIES IN MOTOR SPORT

Spinal injuries are common consequences of accidents at motor sport events. This article explains the correct procedures that motor sport safety workers and medics need to follow when dealing with patients suffering with damage to their spines.

Authors: Dr Michael Kreinest, Dr Michael Scholz, Dr Paul Trafford

(Article republished with full permission from the European Journal of Trauma and Emergency Surgery)

ABSTRACT

Spinal cord injuries can have fatal consequences for injured race car drivers, so prehospital treatment of spinal injuries is therefore a major concern in motor sport.

A structured procedure for assessing trauma patients and their treatment should follow established Airway/cervical spine protection, Breathing, Circulation, Disability, Exposure/environment (ABCDE) principles. Only then, a stable patient could be further examined and appropriate measures can be undertaken. For patients in an acute life-threatening condition, rapid transport must be initiated and should not be delayed by measures that are not indicated. If a competitor must first be extricated from the racing vehicle, the correct method of extrication must be chosen.

To avoid secondary injury to the spine after a racing accident, in-line extrication from the vehicle and immobilisation of the patient are standard procedures in motor sport and have been used for decades. Since immobilisation can be associated with disadvantages and complications, the need for immobilisation of trauma patients outside of motor sport medicine has become the subject of an increasing number of reports in the scientific literature.

Even in motor sport, where specific safety systems that offer spinal protection are present, the indications for spinal immobilisation need to be carefully considered rather than being blindly adopted as a matter of course.

The aim of this article is to use recent literature to present an overview about the treatment of spinal injuries in motor sport. Further, we present a new protocol for indications for immobilising the spine in motor sport that is based on the ABCDE principles and takes into account the condition of the patient.

INTRODUCTION

Injury to the spine occurs in only about 1–2 per cent of trauma patients [71]; close to 20 per cent of these suffer damage to the spinal cord [71]. When multiple injuries are involved, the proportion including spine injuries jumps to almost 34 per cent due to the forces impacting the victim more widely [68]. The percentage of patients with spinal cord injuries is also significantly higher among polytraumatised patients and is stated in the current literature as approximately 8 per cent [1].

In auto motor sport, injuries to the spine are mostly feared by the race drivers [31]. The frequency of spine or spinal cord injuries in the context of motor sport accidents is not exactly known and was the subject of research by the FIA Institute for Motor Sport Safety and Sustainability [68] and more recently by the Global Institute for Motor Sport Safety, the new research partner of the FIA.

In general, the effects of spinal cord injuries have severe and extensive consequences for the patients. To avoid secondary injury, extrication from the race vehicle with the patient in-line and immobilisation of the cervical spine or the entire spine has been standard procedures in motor sport for decades. However, evidence to support these procedures is lacking [1, 23, 43, 66]. For trauma patients outside of motor sport, the questions of immobilisation in general and the choice among various techniques for implementing this measure in particular have become the subject of increasing controversy in the scientific literature.

The aim of this article is to use recent literature to present an overview about the treatment of spinal injuries in motor sport. Further, we present a new protocol for indications for immobilising the spine in motor sport that is based on the ABCDE principles and takes into account the current condition of the patient.

TABLE 1

Search terms utilised in PubMed

Motor AND (sport OR racing)
Cervical spine immobilisation
Spine AND motion
Spine AND protocol
Spine AND [(prehospital) OR (out-of-hospital)]
(Spine AND injury) AND [(prehospital) OR (out-of-hospital)]
(Spine immobilisation) AND [(prehospital) OR (out-of-hospital)]
(Spine immobilisation) AND [(prehospital) OR (out-of-hospital)]
[(Spine injury) OR (spine trauma)] AND [(prehospital) OR (out-ofhospital)]

METHODS

A structured literature search of the United States National Library of Medicine and the National Institutes of Health database was performed using MEDLINE through Pub-Med. The search terms used are listed in Table 1. We considered the literature from 1980 to 2016 and additional articles listed in the reference sections of these articles were also included. Original articles as well as review articles and articles about current guidelines were included. All articles found by the literature search were read in full text by the authors.

A new protocol that supports on-scene decision making for indications for spinal immobilisation after a motor sport accident was developed based on the data and protocols found in the literature. Many criteria found in the literature are intentionally not included in the new protocol as they are usually not applicable in motor sport or because they do not consider circumstances in particular to motor sport.

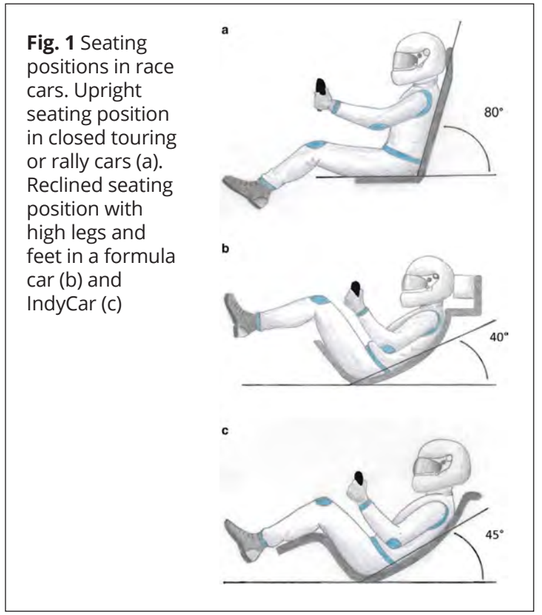


Fig. 1 Seating positions in race cars. Upright seating position in closed touring or rally cars (a). Reclined seating position with high legs and feet in a formula car (b) and IndyCar (c)

Fig. 2 The head and neck support (HANS) is a frontal head restraint device consisting of a shoulder corset (1) and two straps (2) that are fixed at the helmet (3)

RESULTS

The literature search, carried out as described above, yielded 181 articles after removing duplicates. A reference analysis found additional 53 articles. Thus, a total of 234 articles were included and read in full text. The key conclusions were summarised in table format.

SPINAL INJURIES IN MOTOR SPORT

An analysis of injuries with race cars on Fuji Speedway in Japan in the years from 1996 to 2000 showed that injuries to the spine are the most frequent injuries in auto motor sport [61]. Spine injuries are especially common when trauma is the result of excessive impact force. There are many classification systems for injuries to vertebral bodies; however, differentiation due to the mechanism that involves either compression, distraction or rotation is widely recognised [69]. Thus, analysis of the sequence of events characterising the accident can provide key evidence about the mechanism of the injury. Hence, impact of the head against the windshield with axial compression may lead to a compression injury in the spine. When an accident occurs in a vehicle with no or with improperly installed head supports, hyperextension may result in a distraction injury. In cases of high-speed trauma with a range of different forces acting in different directions (e.g., a car accident with a rollover,

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motorcycle accident), the spine may be subject to complex rotation injuries.

In addition, in motor sport the seating position of the driver must be taken into consideration. In closed cars (e.g., touring or rally cars), the driver is sitting almost up right in an anatomical position (Fig. 1a) and the spine is relatively stable with the facet joints engaged. When the driver is in a more reclined seating position, as found in formula cars (Fig. 1b) or IndyCars (Fig. 1c), the seating position induces a flexed spine. Here, the natural anatomical curvature of the spine is compromised by an artificial kyphosis with reversal of the physiological lumbar lordosis. This extra anatomical setting of the spine seems to be a significant factor for fractures of the thoracic spine becoming more evident in rearward direct impacts seen in IndyCars [68] or open-wheel open cockpit race cars [70]. Furthermore, landing impacts after launching effects in formula cars can lead to thoracic or lumbar spine fractures by compression. Stabilisation of the cervical spine is also subject to normal flexion and thus influenced by seating position (Fig. 1).

To minimize the risk of spine injuries, motor sport has a number of additional safety systems in place [60], such as specially designed seats, moulded back supports and head restraints with absorbing foam inserts. There are also special harness restraint systems with up to nine points of fixation to firmly hold the competitor and prevent movement in the seat. Head and neck devices, such as the Head and Neck Support device (HANS, Fig. 2), are a widespread protection system [49]. HANS reduces neck loading, neck tension and shear forces [49] by transferring force via two straps (Fig. 2, 2) that are fixed to the helmet (Fig. 2, 3) to a shoulder corset (Fig. 2, 1). Thus, HANS prevents sudden flexion of the skull and of the cervical spine resulting in reduction of basilar skull fractures and cervical fractures in auto motor sport [69].

In addition, there are also general safety features including the roll cage and the requirement for helmets, as well as special construction features on the raceway [52] that have significant impact on the severity of injuries in the event of high velocity accidents. Experience shows that because of these precautions, the severity of injuries in motor sport must be adjusted compared to the severity of injuries in road cars.

The same is true for motorcycle sports [17] due to especially designed run-off areas and special spine protector systems that are in use.

ASSESSMENT OF TRAUMA PATIENTS WITH SPINAL INJURIES IN MOTOR SPORT

If the preliminary diagnoses made in a prehospital setting are compared with the reliable diagnoses confirmed in the hospital, it is apparent that spine injuries are often underestimated, particularly if there are multiple injuries [35]. Due to limited options in diagnostics in a prehospital setting, only guiding criteria for assessing the possibility of spinal injury can be detected.

First, the mechanisms of the accident should be analysed. If not directly observed and not witnessed by the race control monitors, in most cases wreckage reading and interpreting the surroundings can be informative. Often the race marshals can also provide details about the events and the mechanisms of the accident.

To ensure a structured, focused and prompt assessment of a trauma patient, the initial examination should follow the established ABCDE system (Table 2). The sequence of measures in the ABCDE system follows a strict order to break through the cascade of pathophysiological reactions [26] and has also been established in motor sport [74]. Even if there is strong suspicion of spine trauma, the examination should always follow and complete the ABCDE system.

TABLE 2
The ABCDE concept for treating trauma patients

A	Airway/cervical spine protection
B	Breathing
C	Circulation
D	Disability
E	Exposure/environment

TABLE 3
Motor function of the key muscles to assess spinal cord injury (SCI)

LEVEL OF SCI	IMPAIRED MOTOR FUNCTION
C4	Breathing
C5	Elbow flexion
C7	Elbow extension
L3	Knee extensors
L4	Ankle dorsiflexors
L5	Long toe extensors

Evidence of spinal trauma can be found even as early as during the assessment of the injured driver according to the ABCDE system, however. For example, approximately 45 per cent of spine injuries are present with relevant concomitant injuries [55]. In particular if there is injury to the head, injury to the cervical spine should also be considered [36], which is why a spine trauma is initially assumed for any accident victim with reduced consciousness [48].

Typical symptoms also include pain in the area of the spine, which the patient indicates either at rest or when moved. The entire spine can be inspected and palpated for pain; deformities or stepping during a log roll manoeuvre that is performed while the patient is in-line. The following anatomical landmarks can be used to assess the position or height of a known injury approximately: cricoid cartilage (at the third cervical vertebra, C3), navel (at the tenth thoracic vertebra, T10), and the iliac crest (at the fourth lumbar vertebra, L4). In addition, limitations in mobility or sensitivity disturbances such as numbness or paresthesia may point to additional spinal cord damage.

These symptoms may not be present immediately after the event and may vary in intensity over time. As a part of the initial assessment following the ABCDE principles, a targeted neurological evaluation of the motor and sensory systems is then performed. If the patient's condition is stable and a spinal cord injury is suspected, the key reference muscles (Table 3) can then be assessed. In addition, sensory system deficits can be documented using the most caudal intact dermatome (e.g., paraplegia sub T12). If the trauma has affected spinal nerves or the spinal cord, there may be functional impairment or even complete loss of all motor, sensory and autonomic functions and reflexes (spinal shock) in all regions beyond this point of damage to the spine.

Finally, it is important to note that a patient with a spine injury can exhibit a highly variable clinical presentation. Hence, even patients who are capable of walking after a traffic accident may have a spine injury [57]. Whether the injury to the spine is stable or unstable can only be determined using imaging diagnostics within the hospital.

“IT IS IMPORTANT TO NOTE THAT A PATIENT WITH A SPINE INJURY CAN EXHIBIT A HIGHLY VARIABLE CLINICAL PRESENTATION”

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MANAGEMENT OF TRAUMA PATIENTS WITH SPINAL INJURIES IN MOTOR SPORT

Like the assessment itself, treatment of a trauma patient injured in motor sport follows the ABCDE principles [74]. If the patient is still in the vehicle, once the patient's condition has been evaluated, a decision about the urgency of rescuing and thus about the mode of extrication must be made. A patient's condition can deteriorate at any point moving them into a more urgent category. In motor sport, extrication is a standard procedure that has been refined over many years, with extrication seats developed [35] to facilitate in-line extrication in many instances.

If the patient requires resuscitation or if there is an acute external danger for the patient and the rescue team (e.g., vehicle on fire), an emergency extrication without regard for axis symmetry (e.g., using a Rautek grip) is necessary. In safer situations, the initial assessment using the ABCDE system is completed in situ [74]. If the patient's condition is deemed critical, an urgent extrication takes place with the cervical spine immobilised (typically on a spine board). Full spine immobilisation during the extrication process cannot be ensured in this case and must not take priority because of the patient's condition. A patient who is in stable condition and in a safe situation and for whom there is indication for spine immobilisation is retrieved using an elective extrication with the fullest immobilisation of the spine that is possible (e.g., with the aid of technical rescue). Patients in stable condition can also be introduced to leave the car on their own. This kind of self-extrication leads to less movement of the cervical spine as many other extrication methods in civil cars [26] but is not yet evaluated for race cars.

As soon as the accident victim is in a safer area, treatment follows using the ABCDE system. The following details should be noted with respect to a spine injury:

A—Airway: If possible, immobilisation of the cervical spine should always take place immediately after arriving at a trauma patient [24, 74]. To avoid delay caused by positioning a cervical collar prior to assessing the patient using the ABCDE principles, immobilisation can be achieved by restraining the head using manual immobilisation (Fig. 3). The so-called manual in-line stabilisation is sustained throughout the complete ABCDE assessment and treatment of the trauma patient. Whenever possible, all procedures performed on a trauma patient (airway management, turning manoeuvres, etc.) should be carried out with a minimum of further manipulation of the spine in general and of the cervical spine in particular. Both manual immobilisation and positioning of the cervical collar should not apply any traction on the cervical spine, as this could cause damage to the medulla oblongata (the control centre for the heart and lungs) if there is atlanto-occipital dislocation, for example [9].

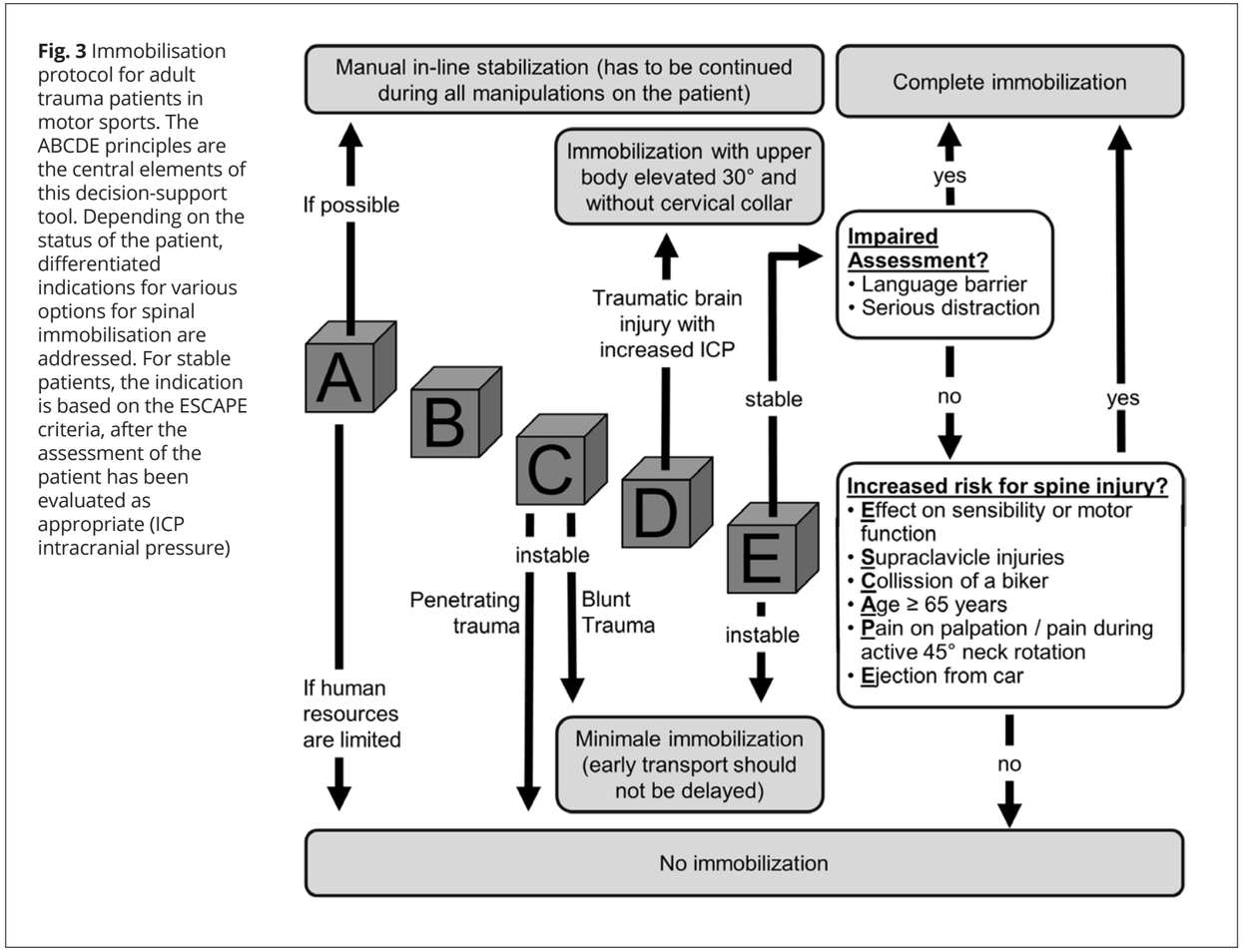

Fig. 3 Immobilisation protocol for adult trauma patients in motor sports. The ABCDE principles are the central elements of this decision-support tool. Depending on the status of the patient, differentiated indications for various options for spinal immobilisation are addressed. For stable patients, the indication is based on the ESCAPE criteria, after the assessment of the patient has been evaluated as appropriate (ICP intracranial pressure)

B—Breathing: If there is suspected injury to the cervical and upper thoracic spine with involvement of the cervical spinal cord, ti≠mely preparation for ventilation should be made, as respiratory disturbances can arise either as a result of disrupted innervation of the diaphragm (C3–C5) or damage to the auxiliary respiratory muscles.

C—Circulation: If the assessment of a crashed race driver indicates unstable circulation, priority for transportation is high. In the event of blunt trauma, immobilisation may be minimised using just a cervical collar (Fig. 3). Although the use of a cervical collar alone does not adequately restrict the mobility of the cervical spine [16, 44, 45], the residual mobility is accepted in this case, taking into account that complete immobilisation would result in delayed transport. According to the literature, trauma patients with unstable circulation following penetrating trauma are not immobilised (Fig. 3). On the other hand, if the assessment of circulation indicates hypotension and bradycardia due to isolated neurogenic shock associated with injury to the cervical or thoracic spinal cord with no other signs of hemorrhagic shock, then treatment with a parasympathetic drug or catecholamines can be administered. Vagus nerve stimulation (e.g., from suctioning or intubation) can magnify bradycardia even to the extent of cardiac arrest. In such cases, temporary use of a pacemaker may be indicated. In contrast to the situation when there are multiple injuries (target systolic blood pressure is 90 mmHg [24]), if the spinal cord is the only injury then normotension should be strived for.

D—Disability: Assessment of a trauma patient for neurological deficit should include checking for signs of severe brain injury or craniocerebral trauma with increased

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TABLE 4

Criteria PRO and CONTRA spinal immobilisation and integration into the protocol for adult trauma patients in motor sport

	Pro/Con	References
Criteria included in the protocol		
Age >65 years	PRO	[4, 30, 65]
State of acute anxiety	PRO	[30]
Language barrier	PRO	[30]
Acute stress reaction	PRO	[13]
Distracting injury	PRO	[4, 13, 59]
MVA ejection	PRO	[4, 27, 65]
Altered/loss of consciousness	PRO	[2, 13, 28–30, 63, 72]
Spine pain/tenderness	PRO	[4, 13, 29, 30, 37, 63, 72]
Abnormal sensory/motor exam	PRO	[4, 28–30, 53, 63, 72]
Significant head or facial injury	PRO	[2, 37, 72]
Supraclavicular lesions	PRO	[53]
No neurological abnormalities	CONTRA	[40, 41]
No midline C-spine tenderness	CONTRA	[40, 41]
No distracting injury	CONTRA	[40, 41, 64]
Able to actively rotate neck	CONTRA	[4, 65]
Functional range-of-motion	CONTRA	[3]
Criteria not included in the protocol		
Rigid vertebral disease	PRO	[72]
Intoxication	PRO	[13, 28, 29, 72]
Fall from >1 m	PRO	[4, 65]
Fall from large animal	PRO	[27]
High speed accident	PRO	[4, 65, 72]
MVA or pedestrian vs. train	PRO	[27]
Vehicle rollover	PRO	[4, 65]
Bicycle collision	PRO	[4, 65]
Road traffic collision	PRO	[38]
Significant intrusion of vehicle	PRO	[4]
Axial load to head	PRO	[4, 65]
Diving accident	PRO	[72]
Sport injuries	PRO	[38]
Shooting	PRO	[38]
Death at scene	PRO	[11, 37]
Other spine fractures	PRO	[72]
Severe injuries to other body systems	PRO	[2, 28, 29, 37, 72]
No evidence of intoxication	CONTRA	[40, 41, 64]
Penetrating trauma	CONTRA	[73]

intracranial pressure. In this case, avoiding the use of a cervical collar is recommended (Fig. 3), as a cervical collar may cause further significant increases to intracranial pressure [20, 46, 62]. However, because cervical spine injuries often coincide with craniocerebral trauma [25], immobilisation using the vacuum mattress is suggested [40]. Even without a cervical collar, a modern vacuum mattress with lateral headrests can achieve excellent immobilisation. Moreover, a supine position with the upper body elevated 30° is possible, which is also recommended for patients with craniocerebral trauma [40]. Alternatively, the patient may be immobilised on a spine board, with which it has been shown that complete immobilisation is possible even without the use of a cervical collar [18].

E—Exposure/environment: Removing the race overalls or other clothing and searching for further injuries may be performed later on necessitated by the situation. This should involve inspection and palpation of the spine. If trauma to the spine is present or suspected, the procedure that follows depends on the patient's condition: if there is an acute and life-threatening status, high priority for transport is given and only minimal immobilisation of the cervical spine should be performed using a cervical collar (Fig. 3). If the patient is stable, further neurological examination could be ruled out. In stable patients without any symptoms of neurological or motor dysfunction, it is necessary to decide on the indication for complete immobilisation using a spine board or vacuum mattress or whether the manual immobilisation that was maintained to this point can be discontinued.

To provide a decision tool for stable patients, literature-based criteria when there is increased risk for spinal injuries (Table 4) were gathered and adapted to the special concerns

"STABILITY AND COMFORT DURING IMMOBILISATION ARE BETTER WHEN A VACUUM MATTRESS IS USED"

of motor sport. The resulting criteria are summarized in the ESCAPE criteria and included in the aforementioned protocol for spinal immobilisation of adult trauma patients in motor sport (Fig. 3). Many criteria found in the literature are intentionally not included in the ESCAPE criteria as they are usually not applicable in motor sport (e.g., fall from height, collision with train or bicycle, diving accident, intoxication) or because they do not consider circumstances particular to motor sport (e.g., high speed accident) or the wording for the criteria was too generalised (e.g., road traffic collision, significant intrusion of vehicle, sport injuries) or in some cases, the criteria are difficult to identify in a prehospital setting (e.g., other spine fractures).

Following the given protocol (Fig. 3), the first assessment to be made with a stable patient is whether the patient can be adequately assessed. Adequate assessment is not possible in the event that there are language barriers or severe distractions (e.g., distracting injuries, states of anxiety, as well as seriously injured or deceased persons at the scene). In such cases, the indication is for complete immobilisation.

If assessment of the patient is not limited, factors that are associated with higher risk of spine injury can be evaluated via the ESCAPE criteria (Fig. 3). According to these criteria, full-body immobilisation should take place if at least one of the following criteria is confirmed: effect on sensibility or motor function, supraclavicular injuries (injuries to the neck or the head), collision of a biker, age greater than 65 years, pain on palpation or during active 45° neck rotation (as well as cervical midline pain at rest), ejection from vehicle. If all ESCAPE criteria can be positively excluded, immobilisation is not necessary (Fig. 3). Since the isolated use of a cervical collar does not provide adequate immobilisation of the cervical spine [20, 46, 62], the given protocol does not distinguish between immobilisation of the cervical spine and the remainder of the spine for stable patients. Full-body immobilisation is recommended in stable patients if there are indications of spine injury for the reasons given above. Reduced immobilisation using a cervical collar on its own and positioning the patient inline on the stretcher is only acceptable for patients in critical condition and with high priority for transport, where ensuring rapid transport is essential (Fig. 3). Stability and comfort during full-body immobilisation are better when a vacuum mattress is used compared to a spine board [36, 48, 55]. However, it is reported that full-body immobilisation on a spine board is less time consuming [57].

Additional treatment for spine injuries

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includes adequate analgesia, because spinal cord lesions, fractures of the spine and any accompanying injuries can cause severe pain. There is no specific drug treatment used in the prehospital setting for spine injuries. Administration of cortisone is no longer recommended [24].

The destination hospital of choice is generally specified in advance at racing events. When there are spinal injuries, the most gentle mode of transport and providing adequate analgesia must be ensured. Rescue by air ambulance typically has a shorter transport time and is smoother [35]. The destination hospital should be equipped with specialists in the treatment of acute spine trauma, as this has a direct influence on the outcome of the patient [56].

Depending on the local facilities, these specialists may be posted in different competence centres (trauma surgery, neurosurgery or orthopedics). In case of spinal cord injury, transport to a centre for paraplegic patients is often secondary. However, both the choice of mode of transport and the destination hospital are initially made exclusively on the basis of the current condition of the patient and the overall pattern of injuries.

DISCUSSION

The use of a cervical collar on its own does not provide full immobilisation of the cervical spine, as there is still obvious mobility remaining. This residual mobility is evident in all models of spinal collars that have been tested [5, 47, 58]. Thus, to protect the spinal column, full immobilisation of the head and trunk is necessary [16, 44, 45]. Furthermore, a cervical collar may compress the jugular veins [8] and, hence, can lead to a significant increase in intracranial pressure [20, 21, 46, 50, 62]. Even complete immobilisation, for example on a spine board, is not without risk. In healthy young men, full immobilisation was associated with restrictive effects on pulmonary function [8]. Furthermore, immobilisation on a spine board may also cause pain [14, 15, 19] and may result in pressure ulcers [10]. Additionally, mouth opening is reduced [42] and airway management is more complicated in immobilised patients [34, 42]. As the severity of patient injury increases, the likelihood of an associated spinal injury also increases [25]. However, clear prioritisation of all procedures is strictly recommended in such patients, as full immobilisation of trauma patients can also be associated with delays [18] and even increase mortality, for example in patients who have suffered a penetrating trauma [39].

Because of these potential complications, the indication for immobilisation needs to be thoughtful, for motor sport accident victims as well [68]. The use of decision-support tools for indication is also recommended by current guidelines, such as those by the German S3 Polytrauma Guideline [24] or the Guideline of the American Association of Neurological Surgeons [67]. Even though adequate treatment of spinal injuries has been a major concern in motor sport for decades, there are, to our knowledge, no decision tools or treatment protocols for prehospital spinal care available in motor sport.

According to the current literature, the FIA started a major research project in 2014 looking at incidence, mechanisms and treatment options of spinal injuries [68] since there has only been a little research published on treatment of injured competitors in motor sport [4]. A number of decision-support tools that have been described in the literature are subject to many limitations. These traditional decision tools were developed for conscious and oriented patients [40, 65]. Many decision tools preclude penetrating [12, 33, 59] or blunt injuries [7]. The current status of the patient (stable or unstable) is not considered [4, 12, 40] or the tool is only applicable if the circulation is already stabilised [65]. Even though a new protocol for spinal immobilisation has been currently provided [51], this decision-support tool could also not be thoughtlessly applied to trauma patients in motors sport, since the mechanisms of accidents as well as the protection systems differ from typical settings in ordinary road traffic accidents. To our knowledge, there is no applicable protocol for indications for spinal immobilisation that consider the patient's current status and are valid for all adult trauma patients in motor sport.

In this article, a decision tool for indication of spinal immobilisation based on the current literature and guidelines and adapted to motor sport specialties is provided. Furthermore, clear indications for the decision of the method of extrication are given. Thus, standardised procedures can be performed as emergency care providers, apart from the motor sport scene, have done them for years. The special structure of the provided protocol allows the integration in the assessment of injured competitors following the ABCDE principles established in motor sport [22, 54]. The same is true for the decision of extrication methods that should also be based on the ABCDE principles [32]. Besides the retrospective analysis about assessment and treatment of injured competitors as currently done at Silverstone Race Circuit [22] and coming up for some German Race Circuits, prospective studies have to prove the benefit of using standardised procedures in emergency care of competitors with spinal trauma as it has been done for trauma patients apart from motor sport [6].

CONCLUSION

Spinal injuries are common in severely injured trauma patients as well as in race drivers. Assessment and management of all trauma patients in motor sport should follow the ABCDE concept of emergency trauma care. Following the ABCDE principles, spinal injuries are not addressed until any acute life-threatening events are handled. Afterwards, further assessment and treatment of spinal injuries and spinal cord injuries may be performed in a stable patient.

Furthermore, the decision about the correct mode of extrication must be made and the indication for spinal immobilisation in general and the immobilisation method in particular has to be provided. Remembering that immobilisation of trauma patients is not without complications according to numerous reports. Therefore, this article presents a new protocol to be considered for immobilisation of adult trauma patients in motor sport, based on the ABCDE principles and oriented to the patient's current status.

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REFERENCES AND RESOURCES

1. Abram S, Bulstrode C. Routine spinal immobilization in trauma patients: what are the advantages and disadvantages? Surg J Royal Coll Surg Edinb Irel. 2010;8:218–22.
2. Agrawal A. Cervical spine clearance: a review and understanding of the concepts. JNMA J Nepal Med Assoc. 2008;47:244–50.
3. Anderson PA, Muchow RD, Munoz A, et al. Clearance of the asymptomatic cervical spine: a meta-analysis. J Orthop Trauma. 2010;24:100–6.
4. Armstrong BP, Simpson HK, Crouch R, et al. Prehospital clearance of the cervical spine: does it need to be a pain in the neck? Emerg Med J EMJ. 2007;24:501–3.
5. Askins V, Eismont FJ. Efficacy of five cervical orthoses in restricting cervical motion. A comparison study. Spine. 1997;22:1193–8.
6. Bandiera G, Stiell IG, Wells GA, et al. The Canadian C-spine rule performs better than unstructured physician judgment. Ann Emerg Med. 2003;42:395–402.
7. Barkana Y, Stein M, Scope A, et al. Prehospital stabilization of the cervical spine for penetrating injuries of the neck—is it necessary? Injury. 2000;31:305–9.
8. Bauer D, Kowalski R. Effect of spinal immobilization devices on pulmonary function in the healthy, nonsmoking man. Ann Emerg Med. 1988;17:915–8.
9. Ben-Galim P, Dreiangel N, Mattox KL, et al. Extrication collars can result in abnormal separation between vertebrae in the presence of a dissociative injury. J Trauma. 2010;69:447–50.
10. Berg G, Nyberg S, Harrison P, et al. Near-infrared spectroscopy measurement of sacral tissue oxygen saturation in healthy volunteers immobilized on rigid spine boards. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 2010;14:419–24.
11. Bortsov AV, Platts-Mills TF, Peak DA, et al. Pain distribution and predictors of widespread pain in the immediate aftermath of motor vehicle collision. Eur J Pain (London, England).2013;17:1243–1251.
12. Burton JH, Dunn MG, Harmon NR, et al. A statewide, prehospital emergency medical service selective patient spine immobilization protocol. J Trauma. 2006;61:161–7.
13. Burton JH, Harmon NR, Dunn MG, et al. EMS provider findings and interventions with a statewide EMS spine-assessment protocol. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 2005;9:303–9.
14. Chan D, Goldberg R, Tascone A, et al. The effect of spinal immobilization on healthy volunteers. Ann Emerg Med. 1994;23:48–51.
15. Chan D, Goldberg RM, Mason J, et al. Backboard versus mattress splint immobilization: a comparison of symptoms generated. J Emerg Med. 1996;14:293–8.
16. Chandler DR, Nemejc C, Adkins RH, et al. Emergency cervicalspine immobilization. Ann Emerg Med. 1992;21:1185–8.
17. Chapman MA, Oni J. Motor racing accidents at Brands Hatch, 1988/9. Br J Sports Med. 1991;25:121–3.
18. Connor D, Greaves I, Porter K, et al. Pre-hospital spinal immobilisation: an initial consensus statement. Emerg Med J EMJ. 2013;30:1067–9.
19. Cordell WH, Hollingsworth JC, Olinger ML, et al. Pain and tissue-interface pressures during spine-board immobilization. Ann Emerg Med. 1995;26:31–6.
20. Craig GR, Nielsen MS. Rigid cervical collars and intracranial pressure. Intensive Care Med. 1991;17:504–5.
21. Davies G, Deakin C, Wilson A. The effect of a rigid collar on intracranial pressure. Injury. 1996;27:647–9.
22. Deakin ND, Roberts I, Collett A, et al. Keeping competitors safe: a four-qear study. Auto + Med. 2015;38–51.
23. Deasy C, Cameron P. Routine application of cervical collars — what is the evidence? Injury. 2011;42:841–2.
24. Deutsche Gesellschaft Für Unfallchirurgie. S3—Leitlinie Polytrauma/ Schwerverletzten-Behandlung AWMF-Register Nr.012/019. 2011.
25. Deutsche Gesellschaft Für Unfallchirurgie (Dgu); Sektion Intensiv- & Notfallmedizin SNa-aDUG. TraumaRegister DGU— Jahresbericht 2014. 2014.
26. Dixon M, O'halloran J, Hannigan A, et al. Confirmation of suboptimal protocols in spinal immobilisation? Emerg Med J EMJ.2015.
27. Domeier RM, Evans RW, Swor RA, et al. The reliability of prehospital clinical evaluation for potential spinal injury is not affected by the mechanism of injury. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 1999;3:332–7.
28. Domeier RM, Evans RW, Swor RA, et al. Prehospital clinical findings associated with spinal injury. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 1997;1:11–5.
29. Domeier RM, Frederiksen SM, Welch K. Prospective performance assessment of an out-of-hospital protocol for selective spine immobilization using clinical spine clearance criteria. Ann Emerg Med. 2005;46:123–31.
30. Dunn TM, Dalton A, Dorfman T, et al. Are emergency medical technician-basics able to use a selective immobilization of the cervical spine protocol?: a preliminary report. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 2004;8:207–11.
31. Ebben WP, Suchomel TJ. Physical demands, injuries, and conditioning practices of stock car drivers. J Strength Condition Res Natl Strength Condition Assoc. 2012;26:1188–98.
32. Floß FM, Balbach P, Scholz M. Extrication. In: Kreinest M, editor. Schwerverletztenversorgung im Motorsport—Das RTTLSKonzept. Berlin: MWV; 2013.
33. Goldberg W, Mueller C, Panacek E, et al. Distribution and patterns of blunt traumatic cervical spine injury. Ann Emerg Med.2001;38:17–21.
34. Goutcher CM, Lochhead V. Reduction in

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mouth opening with semi-rigid cervical collars. Br J Anaesth. 2005;95:344–8.
35. Grohs T, Archer S. Design of an extractable safety seat for the F1 Cockpit. SAE Technical Paper 2000-01-3540. 2000.
36. Hamilton RS, Pons PT. The efficacy and comfort of full-body vacuum splints for cervical-spine immobilization. J Emerg Med.1996;14:553–9.
37. Hanson JA, Blackmore CC, Mann FA, et al. Cervical spine injury: a clinical decision rule to identify high-risk patients forhelical CT screening. AJR Am J Roentgenol. 2000;174:713–7.
38. Hasler RM, Exadaktylos AK, Bouamra O, et al. Epidemiology and predictors of spinal injury in adult major trauma patients: European cohort study. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cervical Spine Res Soc. 2011;20:2174–80.
39. Haut ER, Kalish BT, Efron DT, et al. Spine immobilization in penetrating trauma: more harm than good? J Trauma.2010;68:115–20.
40. Hoffman JR, Mower WR, Wolfson AB, et al. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. N Engl J Med. 2000;343:94–9.
41. Hoffman JR, Wolfson AB, Todd K, et al. Selective cervical spine radiography in blunt trauma: methodology of the National Emergency X-Radiography Utilization Study (NEXUS). Ann EmergMed. 1998;32:461–9.
42. Holla M. Value of a rigid collar in addition to head blocks: a proof of principle study. Emerg Med J EMJ. 2012;29:104–7.
43. Hood N, Considine J. Spinal immobilisaton in pre-hospital and emergency care: A systematic review of the literature. Australas Emerg Nurs J AENJ. 2015;18:118–37.
44. Horodyski M, Dipaola CP, Conrad BP, et al. Cervical collars are insufficient for immobilizing an unstable cervical spine injury. J Emerg Med. 2011;41:513–9.
45. Hostler D, Colburn D, Seitz SR. A comparison of three cervical immobilization devices. Prehospital Emerg Care Off J Natl Assoc EMS Phys Natl Assoc State EMS Dir. 2009;13:256–60.
46. Hunt K, Hallworth S, Smith M. The effects of rigid collar placement on intracranial and cerebral perfusion pressures. Anaesthesia. 2001;56:511–3.
47. James CY, Riemann BL, Munkasy BA, et al. Comparison of Cervical Spine Motion During Application Among 4 Rigid Immobilization Collars. J Athl Train. 2004;39:138–45.
48. Johnson DR, Hauswald M, Stockhoff C. Comparison of a vacuum splint device to a rigid backboard for spinal immobilization. Am J Emerg Med. 1996;14:369–72.
49. Kaul A, Abbas A, Smith G, et al. A revolution in preventing fatal craniovertebral junction injuries: lessons learned from the Head and Neck Support device in professional auto racing. J Neurosurg Spine. 2016;1–6.
50. Kolb JC, Summers RL, Galli RL. Cervical collar-induced changes in intracranial pressure. Am J Emerg Med. 1999;17:135–7.

51. Kreinest M, Gliwitzky B, Schuler S, et al. Development of a new Emergency Medicine Spinal Immobilization Protocol for trauma patients and a test of applicability by German emergency care providers. Scand J Trauma Resusc Emerg Med. 2016;24:71.
52. Leonard L, Lim A, Chesser TJ, et al. Does changing the configuration of a motor racing circuit make it safer? Br J Sports Med. 2005;39:159–61.
53. Lin HL, Lee WC, Chen CW, et al. Neck collar used in treatment of victims of urban motorcycle accidents: over- or underprotection? Am J Emerg Med. 2011;29:1028–33.
54. Lingner M, Scholz B, Kammermayer T, et al. Race Track Trauma Life Support—ein Konzept für die präklinische Behandlung von Schwerverletzten im Motorsport. Dtsch Z Sportmed. 2014;65:160–5.
55. Luscombe MD, Williams JL. Comparison of a long spinal board and vacuum mattress for spinal immobilisation. Emerg Med J EMJ. 2003;20:476–8.
56. Macias CA, Rosengart MR, Puyana JC, et al. The effects of trauma center care, admission volume, and surgical volume on paralysis after traumatic spinal cord injury. Ann Surg. 2009;249:10–7.
57 Mahshidfar B, Mofidi M, Yari AR, et al. Long backboard versus vacuum mattress splint to immobilize whole

spine in trauma victims in the field: a randomized clinical trial. Prehospital Disaster Med. 2013;28:462–5.
58. Mccabe JB, Nolan DJ. Comparison of the effectiveness of different cervical immobilization collars. Ann Emerg Med. 1986;15:50–3.
59. Meldon SW, Brant TA, Cydulka RK, et al. Out-of-hospital cervical spine clearance: agreement between emergency medical technicians and emergency physicians. J Trauma. 1998;45:1058–61.
60. Melvin JW, Begeman PC, Faller RK, et al. Crash protection of stock car racing drivers—application of biomechanical analysis of Indy car crash research. Stapp Car Crash J. 2006;50:415–28.
61. Minoyama O, Tsuchida H. Injuries in professional motor car racing drivers at a racing circuit between 1996 and 2000. Br J Sports Med. 2004;38:613–6.
62. Mobbs RJ, Stoodley MA, Fuller J. Effect of cervical hard collar on intracranial pressure after head injury. ANZ J Surg.2002;72:389–91.
63. Muhr MD, Seabrook DL, Wittwer LK. Paramedic use of a spinal injury clearance algorithm reduces spinal immobilization in the out-of-hospital setting. Prehospital Emerg Care Off J Natl AssocEMS Phys Natl Assoc State EMS Dir. 1999;3:1–6.
64. Myers LA, Russi CS, Hankins DG, et al. Efficacy and compliance of a prehospital spinal immobilization guideline. Int J Emerg Med. 2009;2:13–7.
65. Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients.JAMA. 2001;286:1841–8.
66. Sundstrom T, Asbjornsen H, Habiba S, et al. Prehospital use of cervical collars in trauma patients: a critical review. J Neurotrauma.2014;31:531–40.
67. Theodore N, Hadley MN, Aarabi B, et al. Prehospital cervical spinal immobilization after trauma. Neurosurgery. 2013;72(Suppl 2):22–34.
68. Trafford P, Henderson M, Trammell T. Spinal injuries and motor sport. Auto + Med. 2014;30–41.
69. Trammell T, Hubbard R. Medical and Technical Outcomes of HANS® Use in CART. SAE Technical Paper 2002-01-3350.2002.
70. Trammell TF, K. Spine fractures in drivers of open-wheeled open cockpit race cars. ASPETAR Sports Med J. 2012;1:196–202.
71. Vaillancourt C, Stiell IG, Beaudoin T, et al. The out-of-hospital validation of the Canadian C-Spine Rule by paramedics. Ann Emerg Med. 2009;54(663–671):e661.
72. Vandemark RM. Radiology of the cervical spine in trauma patients: practice pitfalls and recommendations for improving efficiency and communication. AJR Am J Roentgenol.1990;155:465–72.
73. Walters BC, Hadley MN, Hurlbert RJ, et al. Guidelines for the management of acute cervical spine and spinal cord injuries:2013 update. Neurosurgery. 2013;60(Suppl 1):82–91.
74. Wölfl CG, Bouillon B, Lackner CK, et al. Prehospital Trauma Life Support® (PHTLS®). Unfallchirurg. 2008;111:688–94.

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