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Notes

Original article

Epidemiology of cervical spine abnormalities in asymptomatic adult professional rugby union players using static and dynamic MRI protocols: 2002 to 2006

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ABSTRACT

Objective: In this study, the prevalence of abnormalities in the cervical spine of asymptomatic professional rugby players using both static and dynamic magnetic resonance imaging (MRI) in order to improve the detection of abnormalities and prevention of related injuries was investigated.

Design: Prospective observational study.

Setting: French professional rugby union clubs, between 2002 and 2006.

Participants: 206 elite male adult players.

Intervention: Static sagittal T2 and axial T2* fast spin echo (FSE), and dynamic sagittal single-shot FSE weighted MRI scans of the C2–C7 region were examined for the presence of abnormalities. Participants' spines were in supine neutral position for the static protocol but were allowed complete flexibility in a sagittal plane for the dynamic protocol.

Main outcome measurements: The medulla-to-canal ratio (MCR) was measured at every vertebral disc level for both MRI methods. When observed, anatomical abnormalities were categorised.

Results: Anatomical abnormalities mainly consisted of degenerative discopathy and were most frequently observed in players aged ⩾21 years, as well as in players whose MCR was abnormally high based on medical expertise. Most MCRs that were initially assessed as intermediate with static MRI were subsequently assessed as abnormal with dynamic MRI assessment.

Conclusions: Since dynamic MRI is more accurate than static techniques in examining the cervical spine, it contributes substantially to identifying the risk of spinal injuries in professional rugby players, and when used in association with clinical assessment, it can assist in preventing spinal injury.

In the past decade, there have been several studies on cervical spine injuries in cohorts of adult rugby players from different countries, showing that injuries or trauma (concussion) of the cervical spine affected a large proportion of the population of players.[1–4] The only epidemiological observations on the cervical spine of French rugby players were part of a retrospective study involving athletes in a range of sports[5] that found a higher prevalence of stenosis of the cervical canal in rugby players compared with the other sports investigated. However, abnormalities of the cervical spine have not previously been studied on a large scale in professional rugby players.

Until magnetic resonance imaging (MRI) was routinely used as an imaging tool, x rays and CT scans were the standard methods used to calculate the Torg ratio (ratio of the canal to the diameter of the vertebral body) in order to detect stenosis of the cervical spine canal.[6] MRI protocols have now become the method of choice, providing an accurate and specific definition of the soft tissues surrounding the spine.[7] A cine-MRI method (referred to as dynamic MRI in the present study) aimed at screening the cervical spine of rugby players was recently proposed[8] to explore variations in the medulla-to-canal ratio (MCR) throughout the range of motion of the cervical spine. Dynamic MRI can detect abnormalities that can only be seen in extreme positions of the cervical spine (either in hyperflexion or in hyperextension) that may increase the risk of spinal cord injuries.[9 10]

The present research investigates the presence of abnormalities of the cervical spine in asymptomatic professional rugby players, with the purpose of improving the detection of spinal abnormalities and the prevention of related injuries. Two MRI protocols were used—one static with the cervical spine in neutral position and one combining for the first time static images and dynamic (kinematic) sequences of the spine between flexion and extension—both aimed at improving the detection of cervical spine pathology.

METHODS

This study was part of a medical monitoring programme of cervical spine abnormalities undertaken by professional rugby clubs after the French ''Ligue Nationale de Rugby'' (LNR) made it compulsory for all front row professional rugby players in 2002. The screening aims to assess the presence of cervical spine abnormalities that could contribute to increase the risk of both acute and chronic injuries. Informed consent was obtained from each club's medical staff on behalf of the player, and the LNR gave its authorisation to the authors to use the data generated by the screening programme.

Data sets

MRI records were all obtained from professional adult male rugby union players contracted by professional clubs in the first or second divisions of the French championship. Players were aged between 18 and 38 years and were categorised as <21 years or as ⩾21 years. This age threshold was

included in the study because players <21 years hold semi-professional contracts that become fully professional once they turn 21 and pass a medical examination.

Two data sets were used. The first contained static MRI measurements collected during the 2002–2003 and 2003–2004 calendar seasons (each season extends from September to May the following year) and included 127 players. The second data set included measurements of both static and dynamic MRI from 79 players collected during the 2004–2005 and 2005–2006 seasons.

Imaging techniques

The imaging survey was conducted with a 1.5-T Signa HD scanner (GE Healthcare, GE Medical Systems, Milwaukee, Wisconsin, USA) using static sagittal T2-weighted (T2W) fast spin echo (FSE) and axial T2*W (or Cosmic 3-D) for the static protocol, and using dynamic sagittal single-shot FSE (SSFSE) or half-Fourier acquisition single-shot turbo spin echo or fast imaging employing steady-state acquisition (FIESTA) 2-D for the dynamic protocol. Both static and dynamic techniques are described by Adam et al,[8] and the settings for imaging were as outlined in table 1.

Sagittal and axial images and dynamic sequences were taken between the C2 and the C7 cervical vertebrae for each player. For the static protocol, the player was in supine neutral position with total muscular discharge of the cervical spine. This position was held by using a hemicylindrical device mounted on the spine coil ("phase array") and linked to the surface coil to prevent any sagittal movements (fig 1A). For the dynamic MRI, the surface coil was removed in order to allow complete flexibility of the neck and of the head in a sagittal plane between hyperflexion (fig 1B) and hyperextension (fig 1C).

Image assessment

All MRI images were jointly reviewed for the presence of abnormalities by two musculoskeletal radiologists at Capio-Clinique des Cedres (Cornebarrieu, France). The medullar cord and the canal diameters were measured in duplicate at the level of the vertebral disc for each scan for both static and dynamic MRI images. The MCR, also known as cord ratio, was calculated as the diameter of the medulla divided by that of the cervical canal (fig 2). The MCR was measured on median sagittal scans at every vertebral level between C2 and C7. For the dynamic MRI protocol only, the smallest MCR value (arithmetic mean of duplicates) of all MRI-derived measures between flexion and extension was retained for each player. Any difference in the MCRs measured between the static and dynamic protocols was recorded. MCRs were categorised as "0" for normal ratios (<0.6), "1" for intermediate ratios (0.6–0.7) and "2" for abnormal ratios (≥0.7). The 0.6 value was previously used as a reference limit of normality by Berge et al,[5] and the authors of the present study set the 0.7 value as a more realistic lower limit of normal MCRs range, based on their
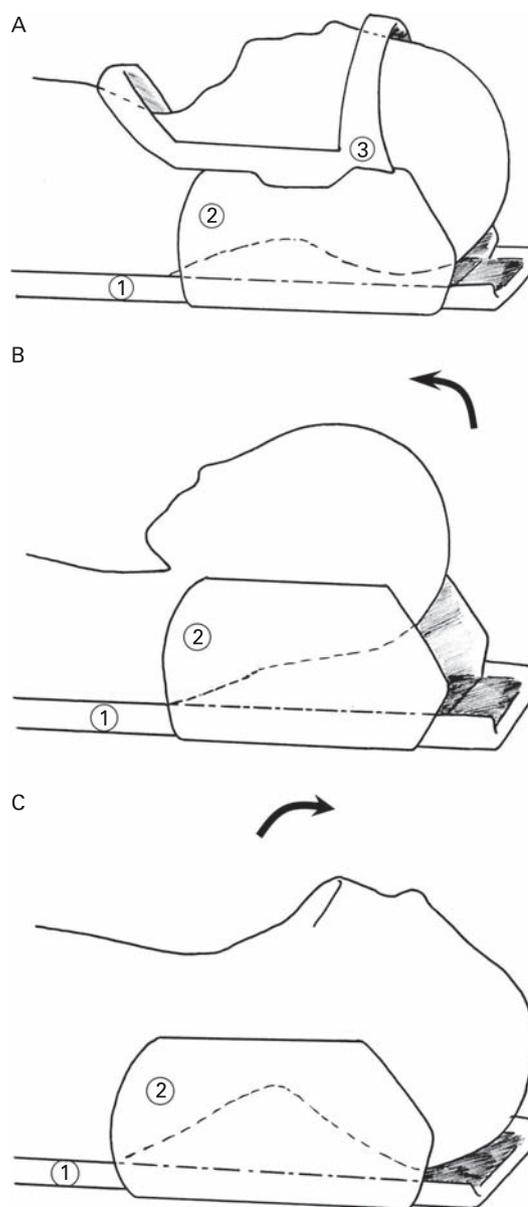

Figure 1 Positions of the cervical spine for the static and dynamic MRI examinations: (A) supine neutral position, (B) hyperextension and (C) hyperflexion. The spine coil (1) is associated with the hemicylindrical device (2) in order to maintain the head and neck in a sagittal plane, unless a surface coil (3) is added to disable any movements.

personal observations and imaging expertise, since there are currently no studies available that set normality standards for the MCR. For both techniques, the cervical spine and its surroundings were examined for the presence of anatomical abnormalities.

Table 1 Settings used for static MRI (sagittal T2W FSE and cosmic 3-D) and dynamic MRI (Fiesta 2-D) protocols

Mode	Time of echo (ms)	Time of repetition (ms)	Slice thickness (mm)	Echo train length	Acquisition time (s)
Sagittal T2W FSE	130	4000	3	NA	NA
Cosmic 3-D	20	500	4	NA	NA
FIESTA 2-D	130	2060	7	62.5	0.825

Cosmic 3-D, axial T2*-weighted; T2W FSE, T2-weighted fast spin echo; FIESTA 2-D, fast imaging employing steady-state acquisition.

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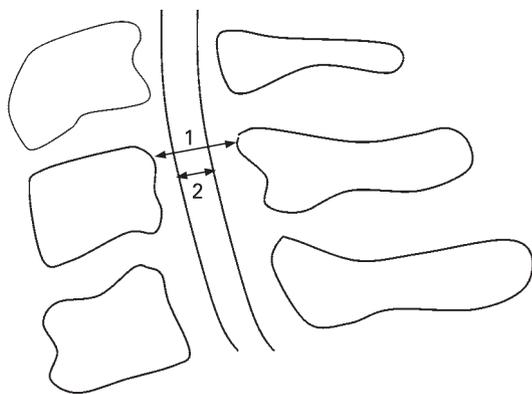
Figure 2 Calculation of the medulla-to-cervical canal ratio (MCR) or cord ratio, obtained by dividing the diameter of the medulla (2) by the diameter of the cervical canal (1).

Statistical analyses

The two data sets were analysed separately, since they were designed independently: the first study comprised all data collected during the 2002–2003 and 2003–2004 seasons, whereas the second study included data from the two following seasons. Statistical analysis of data was undertaken using the Statistical Analyses System (SAS V.9.1, SAS Institute, Cary, North Carolina, USA) computer package. The relative risk (RR) of presenting anatomical abnormalities based on the MCR and age category was calculated for each player in both studies, and the RR of having a narrow cervical spine canal (ie, an abnormal MCR) with regards to age was also estimated. Confidence intervals (95% CI) for RR were calculated. Differences between groups were regarded as significant if the 95% CI did not include 1.00. Regression analyses were performed using the SAS GENMOD procedure. Proportions are given as ratios to the group size with the corresponding percentage between brackets to facilitate visual comparisons between tables.

RESULTS

Static MRI only (2002–2003 and 2003–2004 seasons)

The distribution of MCRs for the 127 players who underwent static MRI screening in the 2002–2003 and 2003–2004 playing seasons is presented in table 2. Of the 57 players <21 years, 12 had an intermediate MCR (0.6–0.7) and a further 8 had an abnormally high MCR (>0.7). For those participants with an intermediate MCR, the risk of injuries directly related to the diameter of the cervical spine canal could not be assessed with certainty, unlike for the eight players whose MCR was beyond 0.7 and who were considered at elevated risk of injuries. These abnormal MCRs were typically located at the C4/C5 and C5/C6 levels of the cervical spine. The distribution of MCRs measured in the 70 players aged ≥21 years was similar to that described in

Table 2 Distribution of medulla-to-canal ratios (MCRs) measured in asymptomatic professional rugby players (n = 127) using static MRI during the 2002–2003 and 2003–2004 seasons

| | Normal (<0.6) (%) | Abnormal | |
		Intermediate (0.6 ≤ MCR < 0.7) (%)	At risk (≥0.7) (%)
<21 years old (n = 57)	37 (65)	12 (21)	8 (14)
≥21 years old (n = 70)	46 (66)	10 (14)	14 (20)

Figure 3 Sagittal view (static MRI) of the cervical spine of a 31-year-old rugby player showing degenerative pathology at the C3/C4 and C5/C6 vertebral levels (arrows).

younger players, with 10 individuals presenting an intermediate ratio and 14 individuals a ratio considered at risk. Age was not related to the risk of having an abnormally high value of MCR (RR 0.99, 95% CI 0.74 to 1.33).

Figure 4 Sagittal view (static MRI) of the cervical spine of a 31-year-old rugby player with a disc hernia (arrow) at the C6/C7 level.

Table 3 Types of anatomical abnormalities observed in asymptomatic adult professional rugby players (102 players out of the 127 examined) between 2002 and 2006

Age	2002–2003 and 2003–2004 seasons (static study only)		2004–2005 and 2005–2006 seasons (static and dynamic study)	
	<21 years old (n = 57)	≥21 years old (n = 70)	<21 years old (n = 25)	≥21 years old (n = 54)
Players with abnormality	12	44	10	35
Degenerative discopathy	9*	34	10	32
Disc hernia	2	17	3†	10†
Abnormal signal of medulla	0	1†	0	1
Atrophy of spinal cord	0	1	0	1
Congenital fusion	0	1†	0	1
Surgical fusion	0	2†	0	0
Morphologic congenital abnormalities of vertebral body	1	0	0	0

*Counts do not add up to the group size given that several different abnormalities could be observed for the same player.
†Also observed with degenerative discopathy.

Anatomical abnormalities were detected in 12 of the 57 players <21 years and in 44 of the players ≥70 years as shown in table 3. The risk of presenting such pathology on the scans was three times higher in participants ≥21 years (RR 3, 95% CI 1.78 to 5.68) and almost twice as high for players with an abnormal (intermediate or at-risk) MCR (RR 1.77, 95% CI 1.05 to 2.99). Degenerative lesions were the most common type of abnormalities regardless of the age category (fig 3); however, older players presented a higher proportion of degenerative discopathy, occasionally associated with lateral or medial disc hernia (fig 4). Other types of lesions found were frequently associated with degenerative processes.

Static and dynamic MRI (2004–2005 and 2005–2006 seasons)
For the 2004–2005 and 2005–2006 seasons, 79 players were examined using both static and dynamic MRI protocols. Table 4 shows the MCRs measured by technique and by age, with 76% of the players <21 years and 61% of the older players having a normal MCR on static MRI scans. These results changed when MCRs were calculated from dynamic scans (fig 5), where four MCRs found normal according to the static technique became intermediate in hyperextension on the dynamic sequence. Likewise, two MCRs that were intermediate on static MRI scans were considered at-risk when the player's spine was in hyperextension. The majority of abnormal MCRs were observed at the C4/C5 and C5/C6 vertebral levels. The number of intermediate MCRs increased by 3% and the number of MCRs at risk (≥0.7) increased by 2% when using the dynamic MRI technique. In the present sample of players, the age

category could not be clearly related to the risk of having an abnormal MCR (RR 1.62, 95% CI 0.65 to 4.01).

Consistent with the 2003–2004 and 2004–2005 season findings, the most common anatomical abnormalities were degenerative lesions in both age categories (table 2). The presence of an abnormal MCR (intermediate or at-risk) calculated from static MRI scans increased by a factor of 3 the risk of showing anatomical abnormality (RR 2.95, 95% CI 1.60 to 5.44).

DISCUSSION
The static MRI study revealed that almost half of the 127 rugby players surveyed in the 2002–2003 and 2003–2004 seasons presented abnormalities of the cervical spine, most of which were degenerative discopathies often associated with disc hernia. This result is similar to that obtained with the static component of the second MRI survey conducted on 79 different rugby players in the 2004–2005 and 2005–2006 seasons. Players aged ≥21 years presented significantly more anatomical abnormalities than younger players in the first study. In the second study, while the point estimate for the relative risk of having anatomical abnormalities for older players was also higher than for younger players, the uncertainty in the estimate meant that the difference between the groups was unclear, and further study with larger samples is required to clarify the extent and direction of the effect. Having a narrower cervical spine canal (MCR≥0.6) increased the risk of presenting anatomical abnormalities by up to three times for both static studies. The dynamic component of the second MRI survey,

Figure 5 Dynamic MRI sequence (selection of three scans) of a 22-year-old player's cervical spine in motion: (A) maximal flexion, (B) neutral position and (C) maximal extension. The arrow in (C) indicates posterior contact of the cervical canal with the medulla at the C5/C6 level. The minimal medulla-to-canal ratios (MCRs) calculated for each scan were in the normal range for (A) and (B) (0.50 and 0.57, respectively), whereas the minimal MCR for (C) (hyperextension) was 0.63, which is considered as an intermediate value in the present study.

Original article
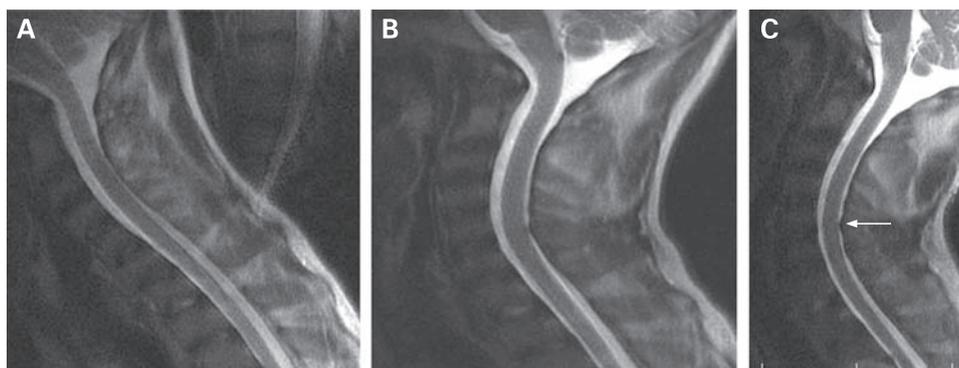
Table 4 Distribution of medulla-to-canal ratios (MCRs) measured in asymptomatic professional rugby players (n = 79) using static and dynamic MRI during the 2004–2005 and 2005–2006 seasons

MCRs	Normal (>0.6) (%)	Abnormal	
		Intermediate (0.6 ≤ MCR < 0.7) (%)	At risk (≥0.7) (%)
Static MRI			
<21 years old (n = 25)	19 (76)	6 (24)	0
≥21 years old (n = 54)	33 (61)	18 (33)	3 (6)
All players (n = 79)	52 (66)	24 (30)	3 (4)
Dynamic MRI			
All players (n = 79)	48 (61)	26 (33)	5 (6)

used for the first time in screening of asymptomatic rugby players, showed changes in the proportion of abnormal MCRs compared with the static examination of the same individuals. Dynamic MRI images provided a more detailed analysis of the cervical spine anatomy, with important variations of the MCR observed between flexion and extension as previously demonstrated in patients diagnosed with degenerative cervical spine changes.[11]

Spinal changes and athlete injuries have been routinely monitored through MRI for the past decade.[5 12 13] However, such studies in rugby players have always been conducted using static protocols similar to the one used in the present study.[14] The novel dynamic protocol in the second study allowed diagnosis of abnormalities of the spinal canal that were not observed or were inconclusive with the static MRI examination alone. This trend had already been reported in a population of patients with degenerative cervical spine pathology and for whom detection of stenosis using cinematic MRI was increased by 22% in flexion and by 65% in extension.[11] To a lesser extent, there were 6% (4/70) more abnormal MCRs measured with the dynamic MRI technique in the present study, and therefore the dynamic MRI technique previously described[8] and applied in the present cohort of players provides a sensitive and reproducible method that could be easily set up with any MRI scanner. MCRs obtained with static MRI and considered at the limit of the ''normality'' criterion for decision making were more sensitively assessed by using the dynamic protocol. It is therefore recommended that MCR measurements between 0.6 and 0.7 for the static protocol be closely reviewed with a combination of clinical investigation (eg, complete neurological examination), including MRI observations of the cervical spine region between flexion and extension to reduce the number of falsely abnormal MCRs.

The proportion of players <21 years diagnosed with a narrow cervical spine canal was clinically important. Although at the beginning of their professional career, these players have been participating in rugby since the age of 12 to 14 years, and therefore, stenosis of the cervical spine cannot be considered exclusively congenital but includes a developmental component

as well. Progressive narrowing of the cervical spine has been shown to be induced by biomechanical factors linked to the practice of rugby as opposed to control athletes competing in non-collision sports.[5] Rugby players also show reduced cervical mobility compared with non-rugby players, and this abnormality is accentuated between young and older players.[15] In addition, an abnormal MCR seems to be more apparent if measured throughout the range of motion of the spine.[11 16] Translation of the C2 vertebrae relative to C7 proportionally diminishes throughout the cervical range of motion, and as such, leads to a significant reduction of the physiological lordosis that protects the cervical spine from impacts. Parameters such as angulations between maximal flexion and maximal extension and translation of C2 relative to C7 could help in quantifying abnormalities acquired through professional-level rugby practise, and these players could be regularly monitored throughout their career. In the future, dynamic MRI protocols could be improved by exerting forces onto the players' cervical spine, in order to recreate game conditions while screening their cervical cord.[17] Putting the players' spines under load could also be done by using a stand-up MRI (Fonar), but this protocol would have a high cost and presents constraining technical conditions such as the magnet's weight (about 130 tonnes).

Before rugby union became professional in the 1990s, physical impacts to the spine mainly affected the front row players, whose compact physique was valuable for winning the possession of the ball in scrums.[18] In contrast, fast-running players like backs would generally avoid tackles from the opposite team, aiming at the score line. The modern rugby game seems to be more physically involved than before the professional era, with more physical confrontations and impacts between players, regardless of the position they hold on the

What is already known on this topic

► Forces and constraints applied to the cervical spine during a rugby game have been commonly associated with early degenerative and arthrosic lesions, especially because of repeated impacts in scrums and tackles.
► In addition, congenital anomalies, such as stenosis and fusion blocks, significantly increase the risk of serious acute injuries.

What this study adds

► Cervical spine injuries, especially chronic lesions, are not only observed in front players, as it used to be for a long time, but also in back players. This could be because of the evolution of the rugby game itself. It is therefore necessary to diagnose pre-existing conditions that potentially increase the injury risk and that lead to early occurrence of degenerative lesions.
► In France, the ''Ligue Nationale'' of rugby has endorsed a systematic survey of cervical spine abnormalities using an optimised combination of static and dynamic MRI in all professional rugby players. This screening programme aims at advising on whether a player is cleared for playing professional rugby or not.

field.[19–22] In response to rugby becoming more of a collision sport, players' morphology has evolved, and their average size and weight have significantly increased over the past decade.[20 22] More demanding game and training schemes may compromise players' longevity at a professional level, but more importantly, their ability to recover from injuries and from asymptomatic chronic impacts.[5 14 23 24] It is therefore critical to consider previous injuries—as defined by the Rugby Injury Consensus Group[21]—as well as existing pathology (whether musculoskeletal or systemic) when assessing players' fitness and their return to play, in order to minimise risks of injury. In France, screening for cervical spine abnormalities is compulsory for professional front row players who are theoretically more at risk of cervical spine acute and chronic impacts, in order to successfully obtain a certificate of ''aptitude to play''. However, backline players are increasingly involved in tackles, mauls, clearing-out phases and associated rucks, and they should also be included in screening surveys for cervical spine abnormalities.[25] The risk of cervical spine injuries is related to extrinsic factors directly associated with the game, including scrummaging, tackles or foul play, as well as intrinsic factors such as anthropometric identity, physical training, recovery period following injuries and fatigue. All these factors are often difficult to consider simultaneously[3] but are essential for the management of injuries in professional rugby.

Serious cervical spine injuries are fortunately rare in rugby union but dramatic when they do occur.[26 27] In contrast, chronic degenerative abnormalities induced by repeated injuries are more frequent, and long-term consequences may well be underestimated, although they form the submerged part of the iceberg.[28] The prime aim of cervical spine screening is to prevent players with morphological abnormalities from putting themselves at a higher risk of injuries than individuals without such anatomical predisposition. Such assessment uses morphological criteria described by Torg *et al*,[9] and the imaging technique chosen to examine the cervical spine remains a crucial factor in order to provide evidence for players and to some extent coaching teams, to make an informed choice about continuing to play.

Today, sports medicine specialists are primarily guided by clinical examinations, and sensitive imaging screening is only used to advise on the players' suitability to continue to play rugby or to return to play following injury.[29 30] This decision usually belongs to the team management. How a medical contraindication to play is used in the decision-making, especially in the presence of cervical spine pathology, becomes especially important given the availability of improved sensitivity of imaging techniques such as dynamic MRI. Yet, a key question that remains unanswered is the specificity of such tests with respect to predicting which players would go on to sustain permanent functional impairment. In the absence of such evidence, the current guidelines for contraindications to play are largely based on clinical expertise. Therefore, it seems evident that consultation of all parties—team management, physiotherapists and sports medicine clinicians—is essential in arriving at a decision that is in the best interest of the player.

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