On-Field and Pitch-Side (Sideline) Assessment of Sports Concussion in Collision Sports: An Expert Consensus Statement Using the Modified Delphi Technique

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Purpose: To perform a Delphi consensus for on-field and pitch-side assessment of sports-related concussion (SRC). Methods: Open-ended questions in rounds 1 and 2 were answered. The results of the first 2 rounds were used to develop a Likert-style questionnaire for round 3. If agreement at round 3 was ::;80% for an item, if panel members were outside consensus, or there were >30% neither agree/disagree responses, the results were carried forward into round 4. The level of agreement and consensus was defined as 90%. Results: Loss of consciousness (LOC) or suspected LOC, motor incoordination/ataxia, balance disturbance, confusion/disorientation, memory disturbance/amnesia, blurred vision/light sensitivity, irritability, slurred speech, slow reaction time, lying motionless, dizziness, headaches/pressure in the head, falling to the ground with no protective action, slow to get up after a hit, dazed look, and posturing/seizures were clinical signs of SRC and indicate removal from play. Video assessment is helpful but should not replace clinical judgment.

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LOC/unresponsiveness, signs of cervical spine injury, suspicion of other fractures (skull/maxillo-facial), seizures, Glasgow Coma Scale score <14 and abnormal neurologic examination findings are indications for hospitalization. Return to play should only be considered when no clinical signs of SRC are present. Every suspected concussion should be referred to an experienced physician. Conclusions: Consensus was achieved for 85% of the clinical signs indicating concussion. On-field and pitch-side assessment should include the observation of the mechanism, a clinical examination, and cervical spine assessment. Of the 19 signs and red flags requiring removal from play, consensus was reached for 74%. Normal clinical examination and HIA with no signs of concussion allow return to play. Video assessment should be mandatory for professional games but should not replace clinical decision-making. Sports Concussion Assessment Tool, Glasgow Coma Scale, vestibular/ocular motor screening, Head Injury Assessment Criteria 1, and Maddocks questions are useful tools. Guidelines are helpful for non-health professionals. Level of Evidence: Level V, expert opinion.

Sports-related concussion (SRC) has been defined as a traumatic brain injury induced by biomechanical forces.[1] The injury is usually caused by an impulsive force transmitted to the head, causing rapid onset of short-lived neurologic impairment that may involve loss of consciousness.[2] SRC is common and accounts for 1.8 million visits to the emergency department.[3] For high schoolaged youth sport, it is estimated that more than 50% of concussions are not related to organized sports but occur during nonorganized sporting activities.[4] Twenty percent of concussions are related to organized school sports, and between 2% and 15% of youth athletes participating in organized sports will experience a concussion within season.[4] The Ivy League-Big Ten epidemiology study reported a total of 1,922 cases of SRCs during 5 athletic seasons from 2013 to 2018.[5] The greatest overall rates occurred in women's lacrosse (1.35 per 1,000 athletic exposures) followed by football (1.26 per 1,000 athletic exposures).[5] During the 2019 Rugby World Cup, 143 injuries were recorded during the 45-match tournament, and 15.4% of these injuries were related to concussion.[6]

On-field and pitch-side assessment of concussion is clinically challenging, and symptoms can range from athletes slowly in getting up after a tackle, headaches, neck pain, nausea, vomiting, dizziness, vertigo, blurred or double vision, to loss of consciousness (LOC).[7,8] Obvious clinical signs of concussions are lying motionless, motor incoordination, ataxia, staggering gait, seizures, and tonic posturing.[7] Identification of concussion is paramount to avoid further injury and reduce the risk of chronic conditions such as chronic traumatic encephalopathy, cognitive deficits, Alzheimer disease,

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Parkinson disease, and motor neuron disease.[8,9] On-field assessment to identify players with suspected concussion, removal from play for further evaluation, and return to play if indicated are critical steps for diagnosis and management of concussion.[8] Head injury assessment tools such as the Sports Concussion Assessment Tool (SCAT), Glasgow Coma Scale, vestibular/ocular motor screening (VOMS), and Maddocks questions are helpful and may assist with clinical decision-making but do not replace a detailed medical examination.[3,5,7,8,10] The 2016 Berlin consensus on concussion in sport suggested that clinical symptoms can include somatic, cognitive, and emotional symptoms; physical signs; balance impairment; behavioral changes; cognitive impairment; and sleep/wake disturbance such as somnolence or drowsiness.[1] When a concussion is suspected, players should be removed from play and multimodal assessment should be conducted.[1] The authors of the 2016 consensus statement acknowledged that the consensus needs to be modified to accommodate new knowledge; the authors also conceded that although agreement exists, management decisions are still based on sound clinical judgment.[1]

In this scenario, a structured approach such as the Delphi method allows experts in a specific field to provide answers where evidence-based medicine cannot provide a clear guideline or is limited by biases, poor study quality, or the inability to reach valid conclusions.[11,12] Therefore, the purpose of this study was to perform a Delphi consensus for the initial on-field assessment for athletes with suspected sports-related concussion. It was hypothesized that consensus would be reached for all items.

Methods

The Delphi panel technique was used as previously described.[11,12] In principle, 3 to 4 rounds of questions are required. For this study, the first round of questions was developed by the steering committee based on submissions from the selected panel. The steering committee then complied the questions for round 1. On completion of round 1, a written summary was provided to the panel and based on the responses from round 1, a second round with open questions was e-mailed to the panel. For round 3, a Likert-style questionnaire was developed and again e-mailed to the panel. For all items in which consensus could not be reached, panel members who were outside consensus were asked to reconsider their answer or justify their response in round 4. Previous recommendations for consensus were suggested to a level of agreement of 80%.[13,14] However, the steering committee believed that a greater level of agreement will reliably reduce bias and achieve solid and valid recommendations and therefore defined consensus as a minimum level of agreement of 90%.[15]

Question Development

The steering group consisted of one experienced researcher/academician who was not a content expert and one experienced sports physician with extensive experience in the field of sports-related head injuries. For question development the clinical guideline published in *Arthroscopy* was used, and the current controversies highlighted in the guideline were identified.[12]

Panel Selection

To select suitable panel members, the current litera- ture was searched on Medline using the search terms "concussion," "head injury," and "sports concussion." Relevant publications were screened, and the senior authors were contacted and invited to participate as panel members. To achieve a broader perspective and increase generalizability of the consensus statement, personal contacts to sports physicians involved with national and international contact sports were used, and these contacts were asked to nominate their ex- perts for sports concussion. The steering committee then invited 20 panel members. Of the 20 invited panel members, 3 colleagues declined participation. One potential panel member declined, explaining that he was currently too busy with other projects; one potential panel member felt that he was no expert in the field; and one potential panel member was not allowed to participate by his employer (professional sporting as- sociation based in the United States). The panel there- fore consisted of 17 recognized and well-published experts in the field, of diverse academic backgrounds, and of experienced sports physicians who served as team physicians of professional clubs at national and international level.

Rounds 1 and 2

For the first round, the panel was asked to provide open-ended questions that they believed were critical for diagnosis and initial on-field management. The steering committee then summarized all responses and compiled 12 initial open-ended questions. These were delivered electronically to the panel (Table 1). The panel was asked to answer the questions in a narrative fashion and argue their case as specifically as possible, using current guidelines or recently published literature if required. Sports physicians who are involved with national and international sporting codes were also asked to base their responses on their specific association or country's guidelines. The results of round 1 were summarized and the controversies and agreements from the first round were highlighted.

Based on these responses, 13 further open and semi-open-ended questions were developed (Table 2). In addition, the panel was asked to rank the importance of clinical signs, assessment methods, criteria for

Table 1. Round 1 Open Questions: On-Field Assessment of Sports-Related Concussion

[1] In your opinion, what are the initial clinical signs of concussion and how do you assess them on-field?
[2] What are the criteria to remove them from the field and perform further clinical tests in the locker room or at the sideline? Or in other words, what are your red flags?
[3] Do you follow any guidelines/ diagnostic criteria with on-field assessment and are these validated and tested? Do you use technology or rely on clinical assessment alone?
[4] What is your initial management? Please differentiate between responsive and nonresponsive scenarios.
[5] What are the criteria for hospitalization?
[6] Are there any criteria that you use to allow athletes to continue to play? Or do you consider symptoms of concussion an absolute indication to remove a player from play?
[7] When taken off field for further evaluation, what tests do you use? In other words, how do you perform sideline assessments and again with or without technology?
[8] Do you believe that cervical spine assessment is mandatory for any player who shows symptoms of concussion?
[9] Only 10% of concussions involve loss on consciousness. What is your view on ATLS-based primary and secondary survey as an important part of concussion assessment?
[10] What are the criteria for coaches and trainers to refer to a physician?
[11] Video assessment
[a] Do you use video assessment?
[b] Do you think it is helpful and how would you use it?
[c] Can you diagnose discussion from video assessment?
[12] Pitch-side assessment
[a] please briefly describe your approach to pitch-side assessment:
assessment tools, referral to hospital, return to play if at all.

ATLS, Advanced Trauma Life Support.

removal from play, and transfer to hospital to determine which of these variables were considered essential. The ranking system was defined as 1 (not important) to 10 (very important). The questions were again delivered to the panel via e-mail.

Rounds 3 and 4

Based on the responses from rounds 1 and 2, controversies and potential agreements were analyzed, and a summary was emailed to the panel members. Likert-style questions were then developed for round 3 (Table 3). Similar to a previous Delphi study,[16] the questions were grouped under subheadings to facilitate easier answering. Panel members who were outside consensus in round 3 were contacted, asked to reassess their responses, and re-rank their agreement for each item outside the 90% consensus level of agreement. If the panel member did not change their assessment, they were asked to provide justification. If consensus was not reached because there were more than 30% of "neither agree nor disagree" responses and the re- sponses were equally distributed between the "strongly agree/agree" and "disagree/strongly disagree" options, panel members who voted "neither agree nor disagree" were asked to commit to an either agree or disagree vote.

Statistical Analysis

The results of rounds 3 and 4 were described as calculated percentiles. Consensus was defined if a minimal level of agreement of 90% was achieved. If there was consensus against a specific item, the results were reported as consensus to disagree.

Results

All 17 panel members completed the first 3 rounds, and all 17 panel members also were required to participate in a fourth round. Twelve of the panel members were registered sports physicians and 4 were employed full-time by an academic institution. Two panel members were neurologists with a focus on concussion and both had academic affiliations. Two panel members were psychologists who specialized in concussion and both were employed full-time by an academic institution. One panel member was an orthopaedic sports medicine fellowship-trained surgeon who is an active team physician for various professional and collegiate collision sports teams. All 17 panel

Table 2. Round 2 Questions: On-Field Assessment of Sports-Related Concussion

[1] Can you please rate the importance of the initial clinical signs of concussion. [1 ¼ not important to 10 ¼ very important]
[2] Can you please rate the importance of the below assessment methods. [1 ¼ not important to 10 ¼ very important]
[3] Can you please rate the importance of the below clinical criteria to remove a player from play. [1 ¼ not important to 10 ¼ very important]
[4] With regards to clinical guidelines, can you please advise which you believe is the most important and comprehensive assessment tool?
[5] If there is a single tool, which of the tools would you consider key?
[6] Do you think clinical examination for on-field assessment is more important than following guidelines? Please reason your case.
[7] Can you please rate the importance of the below clinical criteria to transfer athletes to a hospital. [1 ¼ not important to 10 ¼ very important]
[8] Can you briefly comment on what you believe what the ominous and obvious signs of concussion are.
[9] Should ATLS be mandatory for every health professional who is involved with contact sports and on-field assessment?
[10] Should every suspected concussion be referred to a physician and, if yes, which specialty (i.e., sports physician, neurologist)?
[11] Video assessment is commonly believed to be very helpful for understanding the mechanism of injury. Should every rugby, American football, lacrosse, basketball, and soccer game be recorded to have material available to assess and understand the mechanism of injury. Please consider both professional and amateur level?
[12] How is important video for decision-making during professional matches and should there be a dedicated video concussion doctor?
[13] What would be the signs of concussion on a video recording that would confirm concussion?

ATLS, Advanced Trauma Life Support.

Table 3. Results of Round 3 and 4

	SA	A	N	D	SD	Consensus 3	Consensus 4
Clinical signs of concussion are:							
LOC or suspected LOC	15	2				100	100
Motor incoordination/ataxia	13	4				100	100
Falling to the ground with no protective action	5	10	1	1		88	94
Holding head after impact	3	8	5	1		65	76
Slow to get up after a hit	6	8	2		1	82	94
Dazed look	10	6			1	94	94
Posturing	13	2	1		1	88	94
Balance disturbance	12	4			1	94	100
Confusion/disorientation	14	2			1	94	100
Memory disturbance/amnesia	13	3			1	94	100
Blurred vision, light sensitivity	9	7	1			94	94
Irritability	9	8				100	100
Seizures	12	3	1		1	88	94
Slurred speech	9	7	1			94	94
Slow reaction time	7	10				100	100
Lying motionless	10	7				100	100
Nausea/vomiting	10	5	2			88	88
Dizziness	9	7	1			94	94
Nystagmus	11	3	3			82	82
Headache/pressure in the head	9	7	1			94	94
On-field and pitch-side assessment should include the following:							
Observation of Injury and mechanism	14	3				100	100
Maddocks questions	12	4	1			94	94
Glasgow Coma Scale	10	1	4	2		65	70
Cervical spine assessment	14	1	1	1		88	94
Sideline staff should be asked	8	5	3	1		76	88
Clinical assessment by an experienced health professional	14	3				100	100
Video assessment							
Video assessment should be mandatory for all professional games	12	5				100	100
Video assessment should be mandatory for all college level games	7	5	5			70	76
Video assessment should be mandatory for all amateur level games	1	2	9	5		76	76
A dedicated video physician should be available for all professional games	10	3	2	2		76	82
Video assessment is helpful but does not replace clinical decision making	13	4				100	100
Video assessment is helpful to understand the mechanism of injury	14	3				100	100
Retrospective review of available video material is helpful at all levels	11	6				100	100
In general video assessment can be used to diagnose concussion	1	5	4	4	3	D 41	A 53
Video assessment cannot be used to diagnose concussion but is helpful to confirm the diagnosis and/or raise suspicion	9	8				100	100
Video assessment is not helpful and recognize and remove is more important	1		4	10	2	70	88
Clear signs of concussion with video assessment are							
LOC or suspected LOC	15	2				100	100
Motor incoordination/ataxia	14	3				100	100
Falling to the ground with no protective action	14	3				100	100
Holding head after impact	7	5	3	1	1	70	76
Slow to get up after a hit	6	7	4			76	76
Posturing	15	2				100	100
Balance disturbance	13	4				100	100
Seizures	16		1			94	94
Lying motionless	12	4	1			94	94

(continued)

Table 3. Continued

High tackles or direct head impacts are indirect signs of concussion	5	3	5	2	2	47	47
Clearly dazed	13	4				100	100
Whiplash	4	6	5	1	1	59	64
Unsteady on feet	9	5	3			82	94
Head contact with ground	5	5	6	1		62	62
Not functioning on return to play	9	3	4		1	70	94
Red flagsdremove from play signs are							
LOC or suspected LOC	16	1				100	100
Motor incoordination/ataxia	16	1				100	100
Falling to the ground with no protective action	12	5				100	100
Holding head after impact	2	5	6	4		N 58	A 47/D 35
Slow to get up after a hit	2	7	5	3		53	53
Dazed look	10	6	1			94	94
Posturing	15	2				100	100
Balance disturbance	13	4				100	100
Confusion/disorientation	15	2				100	100
Memory disturbance/amnesia	16	1				100	100
Blurred vision, light sensitivity	9	7	1			94	94
Irritability	4	7	5	1		65	70
Seizures	16	1				100	100
Slurred speech	12	5				100	100
Slow reaction time	9	5	3			82	94
Lying motionless	9	8				100	100
Nausea/vomiting	10	5	2			88	88
Dizziness	8	9				100	100
Nystagmus	10	5	2			88	88
Which guidelines and/or test batteries are useful for both on-field and pitch side assessment							
National Football League Guidelines (U.S.A.)	7	3	6		1	59	94
Australian Physician Guidelines	3	3	10	1			N 52
BokSmart Manual (South Africa)	8	2	6	1		59	70
Head Injury Assessment Tool (HIA)	8	4	5			70	94
SCAT 5	13	3		1		100	100
Maddocks questions	9	6		2		88	100
Balance testing	9	5	1	1		82	94
VOMS	8	8	3		1	94	94
Clinical examination and neurologic assessment	12	3		1	1	88	100
Modified BESS	7	4	5			65	76
World Rugby Protocol	9	4	4			76	88
What are the criteria to allow return to the field to continue to play							
HIA assessment normal	10	5			2	100	100
Normal clinical examination	9	5			3	82	94
Normal video assessment	4	4		3	6	A 47	64
No clinical signs of concussion [see above clinical signs]	10	7				100	100
Need to know the athlete well and trust his reporting	4	7		4	2	65	82
In case there is no team physician or game doctor available: when should coaches or trainers refer to a physician							
every suspected concussion	16	1				100	100
for medicolegal reasons	7	2		7	1	53	70
for any of the aforementioned clinical signs of concussions	13	3		1		94	94
Criteria for hospitalization are							
LOC and unresponsive	12	4			1	100	100
Clinical signs of cervical spine injury	16	1				100	100
Suspicion of other fractures (skull, maxillo-facia)	15	2				100	100
Seizures	15	2				100	100
Glasgow Coma Scale score <14	9	6		1	1	88	100
Headaches		3		9	5	82	52
Prolonged LOC >1 minute	9	3		3	2	70	100
Restlessness, agitation	6	3		4	4	53	82

(continued)

Table 3. Continued

Nausea, vomiting	2	8	4	2	59	82
Abnormal neurologic examination findings	12	2	2	1	82	100
Guidelines and qualifications						
Guidelines are useful as a general guide for non-health professionals at lower-level games	12	4	1		94	94
Any suspicious concussion must be referred to a sports physician	7	6	2	2	76	76
Any suspicious concussion can also be referred to a family doctor, ED physician as long as they have the training to manage concussion	9	6		2	88	100
At professional level there should be at least one physician who is ATLS [or similar training] trained	12	4	1		94	94
At college level there should be at least one physician who is ATLS (or similar training) trained	11	4	2		88	94
At amateur level, there should be at least 1 physician who is ATLS (or similar training) trained	5	4	5	3	53	76
At minimum every coach, trainer should have an updated BLS certificate	11	5	1		94	94

A, agree; ATLS, Advanced Trauma Life Support; BESS, Balance Error Scoring System; BLS, basic life support; D, disagree; ED, emergency department; LOC, loss of consciousness; N, natural; SA, strongly agree; SCAT 5, Sports Concussion Assessment Tool 5; SD, strongly disagree.

members were engaged with professional sporting codes or were the Chief Medical Officer of the code (U.S. Soccer, FIFA [Fédération Internationale De Football Association], National Rugby League Australia, Australian Rules Rugby, South African Rugby, Rugby 7s, U.S. National Football League, National Hockey League, World Netball). Fifteen of the 17 panel mem- bers were actively involved in collision sports as team physicians for various sporting teams and codes at high- school, collegiate, national and international level.

Round 1

The responses for the first round suggested 21 clinical signs that could indicate concussion. On-field assessment should include the observation, mechanism and interpretation of the injury and the sideline staff should be asked for their observations. The cervical spine must be assessed and the Glasgow Coma Scale and Maddocks Questions should be used during the initial assessment. For side-line assessment, 16 clinical signs were suggested that would indicate the presence of SRC. Guidelines that were followed ranged widely and included the BokSmart Manual, National Football League guidelines, Australian Physician Guidelines, Head Injury Assessment Tool, SCAT 5, Video Analysis, Berlin Consensus, Balance Testing, and the World Rugby Protocol. Technology was not used, and 2 panel members believed that clinical experience and examination are most important. Initial management depended on responsive and nonresponsive scenarios. Fourteen criteria were determined that should trigger transfer to an emergency unit and hospitalization. For return to play, the Head Injury Assessment Criteria 1 (HIA 1), normal on-field assessment, and knowing the player well and trusting his or her reporting were considered important. Sideline assessment should include the use of SCAT 5, VOMS, Maddocks Questions, HIA 1, modified Balance Error Scoring System, recording of vital signs, and video footage assessment. Coaches and trainers should refer all athletes with a suspected concussion to a qualified sports physician. Video assessment is believed to be very helpful and diagnosis is potentially possible if there are different viewing angles available and obvious signs of concussion can be established. A summary of the round 1 responses is shown in Appendix Table 1, available at www.arthroscopyjournal.org.

Round 2

In round 2, the importance of clinical guidelines was explored. The panel agreed that more than one clinical guideline could be used but that the SCAT 5 was the most comprehensive tool. Clinical suspicion and assessment were determined to be the gold standard for concussion assessment. The panel was asked to categorize clinical signs into ominous and obvious signs of concussion. The responses are summarized in Appendix Table 2, available at www.arthroscopyjournal.org. The panel agreed that all health professionals should at least have an updated BLS (basic life support) certificate. However, there was no agreement on whether health staff should be trained in advanced trauma life support. Only 65% favored referral to either a qualified sports physician, neurologist, or trained emergency physician if concussion was suspected. Video assessment is a useful tool at the professional level but may not be available at amateur level. A dedicated video concussion doctor should be appointed. Signs of concussion on video assessment include tonic posturing, ataxia, lying motionless, unprotected fall, head contact with the ground, seizures, and obvious balance disturbances. None of these signs can confirm the diagnosis of concussion but raise suspicion and require clinical confirmation. The importance of clinical signs were ranked as follows: LOC or suspected LOC 9.88, seizures 9.71, motor incoordination and ataxia 9.52, posturing

9.5, cognitive disturbance with either confusion or disorientation 9.35, memory disturbance or retrograde amnesia 9.18, uneven gait 8.94, falling to the ground with no protective action 8.71, balance disturbance 8.70, slurred speech 8.65, lying motionless 8.35, dazed look 8.23, oculomotor disturbance 8.11, emotional symptoms 7.53, slow reaction time 7.47, nausea or vomiting 7.41, dizziness 7.00, impaired attention 6.71, slow to get up after a hit 5.47, and holding head after impact 5.06. The assessment methods to be used for an athlete with suspected concussion was ranked as follows: observation of injury and mechanism 9.18, assessment of cervical spine 8.53, the use of Maddocks questions 7.47, Glasgow Coma Scale score 6.71, and ask sideline staff 5.88. Ranking for removal from play were as follows: LOC, deteriorating conscious state, and convulsions 10, disorientation and HIA Criteria I signs 9.68, increasing restlessness 9.44, slurred speech 9.37, ataxia 9.12, player walking in the wrong direction 9.06, neurologic signs 9, severe headaches 8.87, oculomotor signs 8.75, double vision 8.31, suspicion of a high tackle or direct head impact 8.06, neck pain and vomiting 8, and restlessness 7.18. Criteria for transfer to hospital were ranked as follows: suspicion of a skull fracture 10 and any of the following signs that occur within the first 24 to 28 hours after the impact neurologic fallout 9.76, deteriorating restlessness 9.53, unequal pupils 9.47, unresponsive 9.35, convulsions 9.35, Glasgow Coma Scale <13 9.29, slurred speech 9.11, altered LOC 9.11, cervical spine tenderness 8.88, increasing headaches 8.76, prolonged LOC 8.47, and vomiting 7.76.

Round 3

Of the 20 clinical signs of concussion, agreement was reached for 13 items (Table 3): LOC or suspected LOC, motor incoordination/ataxia, balance disturbance, confusion/disorientation, memory disturbance/ amnesia, blurred vision and light sensitivity, irritability, slurred speech, slow reaction time, lying motionless, dizziness, and headaches/pressure in the head. Of the 6 items for on-field and pitch-side assessment, 3 reached consensus (Table 3): observation of injury and mechanism, Maddocks questions, and clinical assessment by an experienced health professional.

Of the 10 items for video assessment of on-field concussions, 5 reached consensus (Table 3): video assessment should be mandatory for all professional games; it is helpful but does not replace clinical decision-making; it is helpful to understand the mechanism of injury; it cannot not be used to diagnose concussion but is helpful to confirm the diagnosis or raise suspicion; and retrospective review of video material is helpful as all levels of play. Of the 15 clinical signs that would clearly indicate that concussion has occurred using video material, consensus was reached for 8 items (Table 3): LOC or suspected LOC, motor incoordination/ataxia, falling to the ground with no protective action, posturing, balance disturbance, seizures, lying motionless and clearly dazed.

Of the 19 red flags that would require removal from play, consensus was reached for 13 items (Table 3): LOC or suspected LOC, motor incoordination/ataxia, falling to the ground with no protective action, dazed look, posturing, balance disturbance, confusion/disorientation, memory disturbance/amnesia, blurred vision/ light sensitivity, seizures, lying motionless, and dizziness. The panel identified 11 guidelines and test batteries that could be useful for on-field and pitch-side assessment. Consensus was reached for 2 items (Table 3): SCAT 5/6 and VOMS.

Of the 5 criteria for return to play, consensus was reached for 2 items (Table 3): normal HIA assessment and no clinical signs of concussion. If there is no team physician or game doctor available, coaches and trainers should refer every suspected concussion to a physician (100% consensus). Similarly, if any of the clinical signs of concussion (Table 3) are present, athletes should be referred to a physician (94% consensus)

Of the 10 criteria for hospitalization, consensus was reached for 4 items (Table 3): LOC and unresponsiveness, clinical signs of cervical spine injury, suspicion of other fractures (skull, maxilla-facial), and seizures. Of the 7 guidelines that should be used and qualifications that should be required for coaches, trainers, staff and health professionals, 3 items reached consensus (Table 3): guidelines are useful as a general guide for non-health professionals at lower-level games; at professional games there should be at least 1 physician who is Advanced Trauma Life Support or similar-trained and at minimum every coach should have an updated BLS certificate.

Round 4

In round 4, the panel reached consensus for 5 addi- tional items with regards to clinical signs of concussion (Table 3): falling to the ground with no protective action, slow to get up after a hit, dazed look, posturing, and seizures. Of the 20 clinical signs that indicate concussion, 17 items (85%) reached consensus in the final round.

For on field and pitch side assessment, the panel reached consensus for 1 more item (Table 3): cervical spine assessment. The panel therefore agreed that 4 of the 6 items (67%) should be considered for on-field and pitch-side assessment.

For the section video assessment, no further items reached consensus. For clear signs of concussion on video assessment, the panel reached consensus on 2 more items (Table 3): unsteady on feet and not functioning on return to play. Of the 15 signs of concussion that should be considered when using video assessment, 10 items (67%) reached consensus in the final round. One more item (slow reaction time) reached

consensus for the red flag removal from play section. Of the 19 signs, 14 items (74%) reached consensus in the final round.

Round 4 did not change consensus for the "what are the criteria for return to the field to continue to play and "when should a player referred to a physician if no team or game doctor is available" sections.

For the criteria for hospitalization, consensus was reached for 4 more items (Table 3): Glasgow Coma Scale score less than 14, prolonged LOC longer than 1 minute, and abnormal findings on neurologic examination. For this section, consensus was reached for 9 of the 10 included items (90%).

Two more items reached consensus for the guidelines that should be used and qualifications that should be required for coaches, trainers, staff, and health professionals (Table 3): Any concussion can also be referred to a family doctor or emergency department physician, as long as they have the training to manage concussion and at college level there should be at least on physician who is Advanced Trauma Life Support (or similar)-trained. For this section consensus was reached for 4 of the 7 included items (57%).

Discussion

In this Delphi Expert Panel Consensus exploring on-field and pitch-side assessment for sports concussion, 10 different relevant areas were assessed. For the "clinical signs of concussion" section, the panel reached a unanimous consensus that LOC, motor incoordination/ataxia, balance disturbance, confusion/disorientation, memory disturbance/amnesia, blurred vision/light sensitivity, irritability, slurred speech, slow reaction time, lying motionless, dizziness, and headache/pressure in the head are clear signs of concussion. Red flags that require removal from play are LOC or suspected LOC, motor incoordination/ataxia, falling to the ground with no protective action, posturing, balance disturbance, confusion/disorientation, memory disturbance/amnesia, blurred vision/light sensitivity, seizures, slurred speech, lying motionless, and dizziness. LOC with unresponsiveness to external stimuli, clinical signs of a cervical spine injury, suspicion of fractures, seizures, Glasgow Coma Scale score of less than 14, and abnormal findings on the neurologic examination should trigger hospitalization. The 2016 Consensus Statement on SRC divides suspected diagnoses into 6 clinical domains: somatic symptoms, physical signs, balance impairment, behavioral changes, cognitive impairment, and sleep/wake disturbance.[1] Feddermann-Demont et al.[7] suggested that a Glasgow Coma Scale score of <13, seizures, severe headaches, fall due to imbalance, acute ocular motor dysfunction, the suspicion of cervical spine disorders, and suspected skull or face fractures are red flags SRC and should not only require removal from play but also indications for hospitalization. Toman et al.[2] also summarized clinical signs of SRC in a narrative review and the clinical signs of SRC were very similar to the results of this Delphi Consensus. However, the authors suggested that behavioral changes such as emotional lability, "do not feel right," feeling like "in a fog" or "slowed down," sadness, nervousness, and anxiousness should also be considered as signs of SRC.[2] Weber et al.[17] reported the main clinical symptoms in athletes hospitalized with SRC. The main symptoms were LOC (41%), headache (36%), retrograde amnesia (29%), nausea (23%), vertigo (21%), and vomiting (11%).[17]

The 2016 consensus suggested that sideline assessment should include assessment of cognitive function and include tools such as SCAT 5 and Maddocks questions.[1] The panel also reached 100% consensus that these 2 assessment tools are useful. In addition, observation of the mechanism of injury and clinical examination by an experienced health professional including a neurologic assessment should be performed as part of the on-field and pitch-side assessment. Feddermann-Demont et al.[7] believe that SCAT and the National Institute for Health and Care Excellence (NICE) criteria are essential tools for pitch-side assessment. Toman et al.[2] also proposed that the NICE guidelines should be used for initial assessment but admit that they lack any advice how to diagnose. Unfortunately, the NICE guidelines are a country-specific protocol and are not applicable to other regions. The panel for this Delphi consensus consisted of international experts, and other country-specific protocols were mentioned by various panel members in rounds 1 and 2. These guidelines were carried forward for a final vote and, as expected, consensus could not be reached. Once could therefore argue that any guidelines or protocols should be applicable internationally and across sporting codes. The 2022 Amsterdam consensus will supersede the 2016 consensus and, hopefully, the new guidelines will consider these arguments. Daly et al.[8] have performed a systematic review and showed that a large variety of test batteries was used with no consistency to quantify SRC. The authors argue that the SCAT assessment is the most widely accepted and deployable test and should be employed more widely.[8] The panel also reached consensus for the HIA assess- ment tool in round 4. Falvey et al.[18] investigated the tool for accuracy, sensitivity, and specificity for HIA. The overall test accuracy was 82%, the sensitivity 77%, and the specificity 66%, and the authors concluded that clinical judgment should be used.[18] HIA might therefore not be the primary tool of choice. VOMS reached consensus in round 3. The VOMS is a tool to screen vestibular ocular motor screening. It has been shown to be highly accurate and reliable.[19-21] Given that the SCAT assessment tool does not include vestibular ocular motor screening, VOMS could be a useful

addition to the SCAT tool when assessing SRC. Although the panel was not asked to consider which combination of tools would be the most comprehensive, one could argue that the combination of SCAT and VOMS would cover most aspects of assessing SRC.

The 2016 consensus noted that video review is a promising approach to improve identification and evaluation of head-impact events, but the consensus statement did not outline specific criteria for SCR. Davis and Makdissi[22] have reported that the lack of protective action, impact seizure, motor incoordination, and blank/vacant look were the highest-ranked video signs. Blank and vacant look had the highest positive predictive value.[23] The panel agreed unanimously that video assessment is helpful in understanding the mechanism of injury and is helpful at all levels but cannot be used to diagnose concussion or replace clinical decision making. However, it should be a mandatory part of all professional games in collision sports. The panel agreed that LOC, motor incoordination/ataxia, falling to the ground with no protective action, posturing, balance disturbance, seizures, lying motionless, clearly dazed, unsteady on feet, and not functioning when returning to play are signs of concussion on video. These signs have also been identified by the panel to be important clinical signs of concussion and are red flags that should trigger removal from play. Obviously, video assessment of concussion is still controversial and reliable parameters for the diagnosis of SRC have yet to be determined.

Return back to the field to play criteria are controversial and no strong scientific evidence exists to judge whether an athlete can return to play.[24] In general, the main criteria include the resolution of clinical symptoms and a normal clinical examination and neurological assessment.[25] Unfortunately, it appears that there is considerable pressure on team physicians to allow premature return to play and it seems crucial to develop clear evidence-based guidelines.[26] The panel agreed that there must be no clinical signs of concussion with a normal clinical examination and normal HIA assessment. There was no consensus as to whether video assessment would be helpful. Interestingly, the panel could not agree on whether personal knowledge of the athlete and trusting his or her reporting could be valuable in deciding on return to the field. Obviously, the panel believed that the focus should be on more reliable clinical and objective signs.

Collision sports is played at all levels and a dedicated team or game physician is not always available. This leads to the question when the present staff such as coaches, trainers, but also physical therapists should refer athletes to a qualified physician. The panel agreed that every suspected concussion should be assessed by a physician and any of the clinical signs identified in this Delphi study require a referral. The panel agreed that guidelines are useful as a general guide for nonhealth professionals at lower-level games but agreed that any athlete with a suspected concussion must be referred to a qualified physician, who does not have to be a sports physician as long as they have the training to manage concussion. This would obviously imply that any athlete at amateur level should not return back onto the field and must be removed from play. One strong argument in favor of guidelines for nonhealth pro- fessionals is that concussion knowledge among sports coaches and match officials is only moderate.[27] How- ever, the majority could identify the most common signs of SRC, understood the importance of removal from play, and that players should only return to play under the guidance of medical advice.[27] At both the professional and college level, there should be at least one physician who is trained in advanced life support or similar; at lower-level games, every coach and trainer should be in possession of an updated BLS certificate. It should be noted that most professional sporting codes have published guidelines and medical standards for their specific sporting code, and medical professionals need to follow these guidelines when they are employed or volunteer to provide medical services at games and tournaments or agreed to be the team physician. The results of this Delphi study summarize the current consensus on various topics with regards to on-field and pitch-side assessment but do not replace the guidelines by the sporting associations.

Limitations

This consensus study has inherent limitations. Obviously, consensus only reflects agreement at a specific point in time, and consensus may change in the future if new evidence is published.[16] Selection of panel members is a crucial aspect and unfortunately standard criteria do not exist.[27] Homogeneity should be avoided and it should be aimed for a diverse panel.[12,27,28] The panel consisted of 17 members, of whom 9 (53%) were associated with rugby. This could have caused bias in favor of rugby-related concussion diagnosis and man- agement. The majority of the panel members were sports physicians, and only 2 neurologists and 2 psy- chologists were included. This could have also resulted in bias.

Conclusions

Consensus was achieved for 85% of the clinical signs indicating concussion. On-field and pitch-side assessment should include the observation of the mechanism, a clinical examination, and cervical spine assessment. Of the 19 signs and red flags requiring removal from play, consensus was reached for 74%. Normal clinical examination and HIA with no signs of concussion allow RTP. Video assessment should be mandatory for professional games but should not replace clinical decision

making. SCAT, VOMS, HIA, and Maddocks questions are useful tools. Guidelines are helpful for nonhealth professionals.

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Appendix

Appendix Table 1. Summary of Responses for Round 1 for On-Field and Pitch-Side Assessment

- [1] In your opinion, what are the initial clinical signs of concussion and how do you assess them on-field?
  - Clinical Signs
    - LOC or suspected LOC
    - Motor incoordination, ataxia
    - Falling to ground with no protective action
    - Holding head after impact
    - Slow to get up after a hit
    - Blank vacant dazed look
    - Fall to ground unprotectedsl
    - Posturing
    - Balance disturbance
    - Uneven gait, instability, ataxia
    - Cognitive disturbance, confusion, disorientation
    - Memory disturbance, retrograde amnesia
    - Oculomotor disturbancedblurred vision, nystagmus, light sensitivity
    - Impaired attention
    - Emotional symptomsdirritability, changes in personality, not feeling right, inappropriate behavior
    - Seizures
    - Speech slurred
    - Slow reaction time
    - Lying motionless
    - Nausea, vomiting
    - Dizziness
    - HIA criteria 1 signs: confirmed or suspected LOC, convulsion, tonic posturing, balance disturbance/ataxia, clearly dazed. Player not orientated in time, place and person, definite confusion, definite behavioural changes, oculomotor signs (e.g., spontaneous nystagmus)
    - HIA criteria 2 signs: head impact event in which diagnosis is not immediately apparent; possible behavior change, possible confusion, injury event witnessed with potential to result in a concussive injury, possible transient or subthreshold criteria 1 signs
  - Assessment
    - Observation of injury and mechanism
    - Maddocks questions
    - Glasgow Coma Scale
    - Ask sidelines staff
    - Assess cervical spine
- [2] What are the criteria to remove them from the field and perform further clinical tests in the locker room or at the sideline? Or in other words what are your red flags?
  - Loss of consciousness regardless of how long
  - Deteriorating conscious state
  - Increasing restlessness, agitation, combativeeunusual behavior
  - Neck pain
  - Severe headache
  - Slurring of speech
  - Disorientation
  - Ataxia
  - Convulsions, tonic posturing
  - Oculomotor signs
  - Double vision
  - Neurologydparesthesia, weakness
  - Restlessness
  - Vomiting
  - Any suspicion of concussion: high tackle, direct head impact or torso, behavioral change
  - Player walks to wrong direction, cannot remember tactical calls, etc.
  - Any of the clinical signs under [1]
  - HIA criteria 1 signs
- [3] Do you follow any guidelines/ diagnostic criteria with on-field assessment and are these validated and tested? Do you use technology or rely on clinical assessment alone?
  - BokSmart Manual [South African Rugby]
  - NFL guidelines
  - Australian Physician guidelines
  - Maddocks Questions
  - Head Injury Assessment Tool
  - SCAT 5
  - Use of video analysis to review suspicious events
  - Most important clinical experience and examination
  - Berlin Consensus
  - Balance Testing
  - World Rugby Protocol for on-field assessment and remove from game
  - Technology not used
- [4] What is your initial management? Please differentiate between responsive and nonresponsive scenarios.
  - Responsive
    - Assess C-spine
    - Quick short memory assessment
    - Brief neurological assessment
    - HIA 1 and 2 criteria: player must be removed from field
    - Remove from field
    - SCAT 5
  - Nonresponsive
    - ABCDE
    - Cervical stabilization
    - Immediate transfer to ER
    - High level oxygen
    - ATLS
- [5] What are the criteria for hospitalization?
  - Unresponsive
  - C-spine tenderness, associated neck pain
  - Suspicion of skull or C-spine fracture
  - Neurologic fallout, localizing signs
  - Unequal pupils
  - Slurred Speech
  - Convulsions
  - Prolonged LOC (more than 1 minute)
  - Altered level of consciousness
  - Any of the following within 24-48 hours: deteriorating GCS, increasingly restless and combative or unusual behavior, repeated vomiting, slurred speech, tingling in the arms and the legs and seizures
  - GCS <13/15
  - Increasing headache
  - Vomiting
  - Deteriorating restlessness or agitation
- [6] Are there any criteria that you use to allow athletes to continue to play? Or do you consider symptoms of concussion an absolute indication to remove a player from play?

(continued)

(continued)

Appendix Table 1. Continued

- HIA criteria 1
- If HIA criteria 1 passed return to play can be considered
- If on-field evaluation and clinical picture confirms no evidence of concussion
- Tests within normal limits
- Know athlete well and trust his reporting
- In elite sports: thorough evaluation of video recording and passing of HIA criteria 1
- Other causes such as musculoskeletal injury or fatigue
- Normal on-field assessment

[7] When taken off field for further evaluation what tests do you use? In other words, how do you perform sideline assessments and again with or without technology?

- SCAT 5
- VOMS
- Maddocks Questions
- Off-field assessment with HIA 1
- Vital signs
- Neurological assessment including cranial nerves
- Video footage if available
- Assessment of player when player is known to me
- Modified BESS

[8] Do you believe that cervical spine assessment is mandatory for any player who shows symptoms of concussion?

- Yes, critical after checking of airway
- Should be mandatory, systematic approach i.e., ATLS

[9] Only 10% of concussions involve loss on consciousness. What is your view on ATLS based primary and secondary survey as an important part of concussion assessment?

- Good guidelines are important to avoid missing injuries. Should be compulsory.
- A good alternative is: ABCDE (Airway and cervical spine, Breathing, Circulation, Disability or neurological fallout, Exposure)
- Maddock and SCAT are more important for concussion
- If Glasgow Coma Scale is 15/15 survey not so important
- Only important if major impact

[10] What are the criteria for coaches and trainers to refer to a physician?

- Coaches and trainers should know their athletes better, and when an athlete 'seems off' after an incident, they should refer them for assessment. As stated previously, LOC, off balance, and headaches should prompt referral for assessment.
- Every suspected concussion should be referred to a physician
- Consider medico-legal responsibility

[11] Video assessment

[a] Do you use video assessment?

- Majority of the panels uses video assessment
- Some believe it is compulsory at elite level

[b] Do you think it is helpful and how would you use it?

- Very helpful to understand mechanism
- Typical indirect signs for concussion: LOC, posturing, seizure, balance disturbance, clearly dazed
- Helpful to prevent catastrophic events and adjust playing rules

[c] Can you diagnose concussion from video assessment?

- Possible if viewed from different angles
- Yes, HIA criteria 1 easily identifiable
- Can identify observable signs such as lying motionless after falling without protecting oneself, as well as stumbling/ motor incoordination and seizure activity, but cannot diagnose concussion

(continued)

Appendix Table 1. Continued

- No concussion is a clinical diagnosis
- Useful as an aid, clinical evaluation warranted
- Very helpful and a dedicated review physician should be employed.

[12] Pitch-side assessment: please briefly describe your approach to pitch-side assessment: assessment tools, referral to hospital, return to play, if at all.

- ABCDE rule
- SCAT 5
- Maddocks Questions
- Clinical assessment in locker room
- HIA 1 assessment
- Full neurologic examination
- VOMS

ATLS, Advanced Trauma Life Support; BESS, Balance Error Scoring System; GCS, Glasgow Coma Scale; HIA, Head Injury Assessment Criteria; LOC, loss of consciousness; NFL, National Football League; SCAT 5, Sports Concussion Assessment Tool 5; VOMS, vestibular/ ocular motor screening.

Appendix Table 2. Responses for On-Field and Pitch-Side Assessment

[3.1] With regards to clinical guidelines, can you please advise which you believe is the most important and comprehensive assessment tool?
- No single most important tool
- Need several tools þ observation of the injury event þ clinical acumen and experience
- Many feel that SCAT 5 is the most comprehensive tool
- Some feel it should be complemented by HIA 1 and neurocognitive tests such as ImPACT or Cogstate
- Clinical suspicion and assessment are generally seen as the gold standard
- Combination of witnessing mechanism (live/via video); clinical assessment of symptoms plus neurologic, cognitive, oculomotor, and balance assessments

[3.2] If there is not a single tool which combination of tools would you consider key?
- The majority prefer to use SCAT 5 and combine with other tools such as VOMS, ImPACT, and neurocognitive tests
- Some would like to review video assessment if available
- The importance of clinical assessment is again stressed
- One panel member believes that oculovestibular function screening is imperative

[3.3] Do you think clinical examination for on-field assessment is more important than following guidelines? Please reason your case.
- The majority believe that on field clinical assessment and judgment is important. Clinical skills and experience clinicians are critical and supersede guidelines.
- The key-term is to recognize and remove.
- Guidelines are just a guide but possibly important for community nonexperienced sideline staff and nonhealth care staff.
- Guidelines also useful as a general protocol for management and recognition of possible concussion cases. This is especially important, as many concussions occur in the nonelite or amateur settings, which require guidelines and protocols. In this environment, they provide a framework for care.
- Some believe that SCAT 5 should be considered.

[1.3] Can you briefly comment on what you believe what the ominous and obvious signs of concussion are.

Ominous signs: One pupil is larger, worsening headaches, slurred speech, convulsions/seizures, neurological fallout, confusion, loss of consciousness, repeated vomiting/nausea, drowsiness, unusual behavior, in general worsening of symptoms, when remove from stimulation failure to improve, oculomotor signs/nystagmus, dangerous injury mechanism, clutching of the head, motionless on ground, neck pain/tenderness, weakness, seizures, double vision, increasing restlessness/agitation, incisive incident, ataxia, blank stare

Obvious signs: headache/pressure in the head, nausea/vomiting, balance problems, double/blurry visions, confusion/concentration/memory problems, "not feeling right," loss of consciousness, deterioration in consciousness, unresponsive, seizure, posturing, ataxia, behavior changes, seizures, dazed/blank look, confusion, no protective action in falling, criteria 1 signs

[9.1] Should ATLS a mandatory for every health professional who is involved with contact sports and on-field assessment?
- All should have BLS, First aid in rugby and intermediate care in rugby with higher level play
- Yes: 14/17
- Alternative: level 3 course immediate care in rugby 3/17
- Yes, at professional level
- Should be at least on physician with ATLS or level 3 course
- No. If not accessible, better to have non-ATLS there than nobody

[10.1] Should every suspected concussion be referred to a physician and if yes which specialty [i.e., physician, neurologist]?
- Yes, should be standard practice
- Yes. Sports physician 11/17
- Yes, well-educated and experienced physician: sports physician or neurologist, ED physician 10/17
- CAVE just being a sports physician does not make you qualified to manage concussion
- No just needs an experienced physician who is qualified to manage concussion

[11.1] Video assessment is commonly believed to be very helpful for understanding the mechanism of injury. Should every rugby, American football, Lacrosse, Basketball and Soccer game be recorded to have material available to assess and understand the mechanism of injury? Please consider both professional and amateur level.
- Yes 9/17
- Yes, at professional level 8/17
- Yes, helpful but cost dependent and may not be practical at amateur level
- Yes, even cell phone footage can be useful
- No. It is helpful, but not essential 2/17
- No at amateur: recognize and remove
- No: video review valuable but simple recording can be misleading

[11.2] How is important video for decision making during professional matches and should there be a dedicated video concussion doctor?
- Important/very important 13/17
- Dedicated video concussion doctor 10/17
- Multiple angles critical
- Helpful but not essential 3/17
- Training needed
- Clinical picture most important 2/17
- Not feasible for soccer

(continued)

Appendix Table 2. Continued

[11.3] What would be the signs of concussion on a video recording that would confirm concussion?
Tonic posturing, ataxia, confirmed or suspected LOC, slow to get up, lying motionless, unprotected fall, clearly dazed, unsteady on rising and on feet, head impact, whiplash, head contact with ground, seizures, not functioning on RTP, balance disturbances, motor incoordination, falling back to the ground 3/17 No obvious signs on video that confirm concussion but raises suspicion: LOC, ataxia, seizure

ATLS, Advanced Trauma Life Support; BLS, basic life support; ED, emergency department; HIA, Head Injury Assessment Criteria; ImPACT, immediate post-concussion assessment and cognitive testing; LOC, loss of consciousness; RTP, return to play; SCAT 5, Sports Concussion Assessment Tool 5; VOMs, vestibular/ocular motor screening.