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Grading and assessment of clinical predictive tools for paediatric head injury: a new evidence-based approach

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Abstract

Background: Many clinical predictive tools have been developed to diagnose traumatic brain injury among children and guide the use of computed tomography in the emergency department. It is not always feasible to compare tools due to the diversity of their development methodologies, clinical variables, target populations, and predictive performances. The objectives of this study are to grade and assess paediatric head injury predictive tools, using a new evidence-based approach, and to provide emergency clinicians with standardised objective information on predictive tools to support their search for and selection of effective tools.

Methods: Paediatric head injury predictive tools were identified through a focused review of literature. Based on the critical appraisal of published evidence about predictive performance, usability, potential effect, and post-implementation impact, tools were evaluated using a new framework for grading and assessment of predictive tools (GRASP). A comprehensive analysis was conducted to explain why certain tools were more successful.

Results: Fourteen tools were identified and evaluated. The highest-grade tool is PECARN; the only tool evaluated in post-implementation impact studies. PECARN and CHALICE were evaluated for their potential effect on healthcare, while the remaining 12 tools were only evaluated for predictive performance. Three tools; CATCH, NEXUS II, and Palchak, were externally validated. Three tools; Haydel, Atabaki, and Buchanich, were only internally validated. The remaining six tools; Da Dalt, Greenes, Klemetti, Quayle, Dietrich, and Güzel did not show sufficient internal validity for use in clinical practice.

Conclusions: The GRASP framework provides clinicians with a high-level, evidence-based, comprehensive, yet simple and feasible approach to grade, compare, and select effective predictive tools. Comparing the three main tools which were assigned the highest grades; PECARN, CHALICE and CATCH, to the remaining 11, we find that the quality of tools' development studies, the experience and credibility of their authors, and the support by well-funded research programs were correlated with the tools' evidence-based assigned grades, and were more influential, than the sole high predictive performance, on the wide acceptance and successful implementation of the tools. Tools' simplicity and feasibility, in terms of resources needed, technical requirements, and training, are also crucial factors for their success.

Keywords: Paediatric head injury, Clinical prediction, Clinical decision support, Grading and assessment, Evidence-based, Emergency medicine

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Background

Clinical decision support (CDS) systems proved to enhance evidence-based clinical practice and improve healthcare cost-effectiveness [1–6]. Based on Shortliffe's three levels classification, clinical predictive tools, here referred to simply as predictive tools, belong to the highest CDS level; providing patient-specific recommendations based on clinical scenarios, which usually follow clinical rules and algorithms, cost benefit analysis, or clinical pathways [7, 8]. These research-based applications quantify the contributions of relevant patient characteristics to derive the likelihood of diseases, predict their courses and possible outcomes, or support the decision making on their management [9–11]. Among the healthcare areas that are increasingly utilising predictive tools is the emergency department (ED) [11, 12]. Some of these tools have been demonstrated to support EDs to overcome many of the encountered challenges, such as overcrowding of patients, lack of resources, variable acuity and diversity of clinical conditions [13, 14]. They also have the potential to help clinicians to improve effectiveness through achieving better clinical outcomes, improve efficiency by reducing costs, and improve patient safety by minimising complications and unintended consequences [15–17].

Traumatic brain injury (TBI) is one of the most commonly presenting emergency conditions and is the leading cause of death and disability among trauma patients [18, 19]. In 2017, the centers for disease control and prevention (CDC) reported that the annual TBI related ED visits were estimated at 2.5 million incidents in the United States (US) [20]. Approximately, one third of these incidents occurred among children aged 0 to 14 years [21]. Many predictive tools have been developed, over the last 25 years, to support the diagnosis of TBI among children and guide the use of computed tomography (CT) in the ED [22, 23]. Through predicting TBI and identifying children who are at low risk of clinically important incidents, these tools are designed to decrease CT scan over-utilisation, to save time and money, and to minimise the exposure of children to the harmful ionising radiation, without compromising their safety or missing clinically significant events [24–28].

When selecting a predictive tool, for implementation at their clinical practice or for recommendation in clinical practice guidelines, clinicians involved in the decision making are challenged with an overwhelming and ever-growing number of tools. Many of these tools have never been implemented or assessed for comparative effectiveness or post-implementation impact [29–31]. Currently, clinicians rely on their previous experience, subjective evaluation or recent exposure to predictive tools in making selection decisions. Objective methods and evidence based approaches are rarely used in such decisions [32, 33]. Some clinicians, especially those developing clinical guidelines, search the literature for the best available published evidence. Commonly they look for studies that describe the development, implementation or evaluation of predictive tools. More specifically, some clinicians look for systematic reviews on predictive tools, comparing their development processes or predictive performances. However, there are no available methods to objectively and comprehensively summarise and interpret such evidence [34, 35].

While there are many predictive tools that have been developed, to help clinicians rule out TBI among children at the ED, only a few were considered for use in clinical practice [22–24]. Therefore, we need to understand what makes certain tools more widely accepted and successfully implemented than the others. This will help national and institutional guideline developer clinicians to make better decisions in selecting and incorporating effective predictive tools in their clinical guidelines to help other clinicians through the decision-making process. Furthermore, this will also help expert clinicians develop better predictive tools for the clinical practice in the future. In addition to the predictive performance measures, such as the sensitivities and specificities of predictive tools, many other quantitative and qualitative measures can be considered for the analysis. The country and year of tools' development could have an influence on the tools' acceptance and success. In addition, the number of citations and studies that report the tools' validation, evaluation or implementation could indicate some sort of attention and acceptance. Furthermore, the quality of the tools' development studies, and the efforts invested in their development, reflected in the sample size of patients or records used in the development and the number of authors and their experiences, could support tools' wide acceptance and successful implementation.

The primary objective of this study is to grade and assess paediatric head injury predictive tools using a new evidence-based framework for grading and assessment of predictive tools (The GRASP Framework). The secondary objective is to provide emergency clinicians with standardised objective information on clinical predictive tools to support their search for and selection of effective tools.

Methods

Our study is composed of three parts. The first includes identifying paediatric head injury predictive tools, proposed in the literature, and their related published evidence. The second part includes grading these predictive tools using our new evidence-based approach and eligible published evidence. The third part includes conducting a comprehensive and objective analysis to answer the research question.

Identifying predictive tools

We conducted a focused review of the literature on paediatric head injury predictive tools. The concepts used in the literature search included "paediatrics", "head", "injury", "clinical prediction", "tools", "rules", "models", "development", "validation", "implementation", and "evaluation". The search was conducted for studies published in English language, with no specific time frame, using MEDLINE, EMBASE, CINAHL, and Google Scholar. The default time range of each database was used, including available publications since 1879, 1950, 1947, and 1937 respectively and up to January 2019. The search followed five steps. 1) Systematic reviews on paediatric head injury predictive tools were identified and retrieved. 2) Examining the systematic reviews; the primary studies, describing the development of the tools, were then identified and retrieved. 3) All secondary studies that cited the primary studies or that referred to the tools' names or to any of their authors, anywhere in the text, were retrieved. 4) All tertiary studies that cited the secondary studies or that were used as references by the secondary studies were retrieved. 5) Secondary and tertiary studies were examined to exclude non-relevant studies or those not reporting the validation, implementation or evaluation of the tools. Additional file 1: Figure S2 shows the process of searching the literature for the paediatric head injury predictive tools and their related published evidence.

Grading predictive tools

Each paediatric head injury predictive tool was evaluated using our newly developed framework for grading and assessment of predictive tools (abbreviated as GRASP) [36]. Eligible studies were examined in detail for the reported evaluations of the predictive tools. Based on the critical appraisal of the published evidence on predictive tools, the GRASP framework uses three dimensions to grade predictive tools: 1) Phase of Evaluation, 2) Level of Evidence and 3) Direction of Evidence.

Phase of evaluation

Assigns A, B, or C based on the highest phase of evaluation. If a tool's predictive performance, as reported in the literature, has been tested for validity, it is assigned phase C. If a tool's usability and/or potential effect have been tested, it is assigned phase B. Finally, if a tool has been implemented in the clinical practice, and there is published evidence evaluating its post-implementation impact, it is assigned phase A.

Level of evidence

A numerical score, within each phase, is assigned based on the level of evidence associated with each tool. A tool is assigned grade C1 if it has been tested for external validity multiple times, grade C2 if it has been tested for external validity only once, and grade C3 if it has been tested only for internal validity. Grade C0 means that the tool did not show sufficient internal validity to be used in the clinical practice. Grade B1 is assigned to a predictive tool that has been evaluated, during the planning for implementation, for both of its potential effect, on clinical effectiveness, patient safety or healthcare efficiency, and for its usability. Grade B2 is assigned to a predictive tool that has been evaluated only for its potential effect, while if it has been studied only for its usability, it is assigned grade B3. Finally, if a predictive tool had been implemented then evaluated for its post-implementation impact, on clinical effectiveness, patient safety or healthcare efficiency, then it is assigned grade A1 if there is at least one experimental study of good quality evaluating its post-implementation impact, grade A2 if there are observational studies evaluating its impact, and grade A3 if the post-implementation impact has been evaluated only through subjective studies, such as expert panel reports.

Direction of evidence

For each phase and level of evidence, a direction of evidence is assigned based on the collective conclusions reported in the studies. The evidence is considered positive if all studies about a predictive tool reported positive conclusions and negative if all studies reported negative or equivocal conclusions. The evidence is considered mixed if some studies reported positive and some reported either negative or equivocal conclusions. To decide an overall direction of evidence, a protocol is used to sort the mixed evidence into 1) Mixed evidence that supports an overall positive conclusion or 2) Mixed evidence that supports an overall negative conclusion. This protocol is based on two main criteria; 1) Degree of matching between the evaluation study conditions and the original tool specifications, and 2) Quality of the evaluation study. Studies evaluating predictive tools in closely matching conditions to the tool specifications and providing high quality evidence are considered first; taking into account their conclusions in deciding the overall direction of evidence.

The final grade assigned to a tool is based on the highest phase of evaluation, supported by the highest level of positive evidence, or mixed evidence that supports a positive conclusion. The GRASP framework concept is shown in Fig. 1 and the GRASP framework detailed report is presented in Additional file 1: Table S3.

Results

Identifying predictive tools

We identified five systematic reviews [22–24, 27, 28] and two literature reviews [37, 38] discussing paediatric head injury predictive tools. Through these seven reviews, we identified 16 studies describing the development and internal validation of 14 distinct predictive tools [39–54]. After development and internal validation, the PECARN

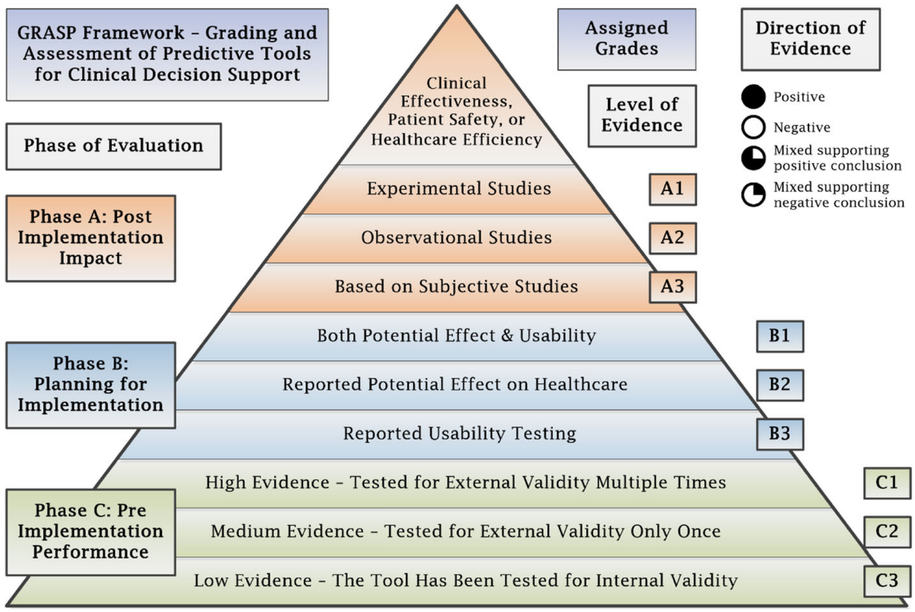

Fig. 1 The GRASP Framework Concept [36]

rule (Paediatric Emergency Care Applied Research Network) [49] was evaluated in 23 studies [55–77]. The CHALICE rule (Children's Head injury ALgorithm for the prediction of Important Clinical Events) [43] was evaluated in 13 studies [24, 48, 58–62, 66, 69, 72, 77–80]. The CATCH rule (Canadian Assessment of Tomography for Childhood Head injury) [51] was evaluated in 11 studies [48, 58–61, 63, 66, 72, 81–83]. The NEXUS II rule (National Emergency X-Radiography Utilization Study) [50, 54] was evaluated in four studies [48, 84–86]. Palchak rule [52] was evaluated in two studies [48, 87]. On the other hand, none of the remaining nine rules; Haydel [47], Atabaki [39], Buchanich [40], Da Dalt [41], Greenes [44, 45], Klemetti [48], Quayle [53], Dietrich [42], or Güzel [46] were evaluated in published studies after their initial development.

Grading predictive tools

Using the GRASP framework and eligible evidence, we assigned grades to the 14 paediatric head injury predictive tools. The **PECARN** rule was developed by Dr. Nathan Kuppermann in the US in 2009 and was tested successfully for internal validity [49]. The rule was tested multiple times for external validity and proved externally valid in all the reported studies [56, 58–61, 63, 66, 67, 70–74, 76, 77]. This qualifies the PECARN rule for grade C1. Four economic analysis studies discussed the positive potential effects of using the PECARN rule on lowering healthcare costs, decreasing the frequency of using CT scans and minimising the exposure of children to harmful ionising radiation [62, 68, 69, 75]. This qualifies the PECARN rule for grade B2. Three observational post-implementation impact studies were conducted. One study concluded that the PECARN intermediate-risk predictors did not play a major role in the physicians' decision to perform a CT scan [65]. However, the other two studies concluded that implementing and using the PECARN rule was associated with a statistically significant decrease in CT utilisation without safety or effectiveness issues [57, 64]. Using the protocol, the mixed evidence here supports positive conclusion on the post-implementation impact of the PECARN rule. Accordingly, the final grade assigned to the PECARN rule is A2.

The **CHALICE** rule was developed by Dr. Joel Dunning in the United Kingdom in 2006 and was tested successfully for internal validity [43]. The rule was tested multiple times for external validity and proved externally valid in all the reported studies [48, 58–61, 66, 72, 77]. This qualifies the CHALICE rule for grade C1. Six cost-effectiveness studies discussed the potential effects of implementing the rule; whether it would increase or decrease the number and costs of CT scans and its potential effect on the exposure of children to radiation. Two of the six studies in 2010 reported that the implementation of CHALICE rule would increase the number of CT scans performed and increase the exposure of children to the harmful ionising radiation [79, 80]. However, four subsequent studies in 2011, 2013, 2015 and 2016 reported that implementing the CHALICE rule would be a cost-effective strategy to safely reduce unnecessary head CT scans [24, 62, 69, 78]. Using the protocol, the mixed evidence here supports positive conclusion on the cost-effectiveness and potential effects of implementing the

CHALICE rule. The rule was not evaluated for usability or post-implementation impact. Accordingly, the final grade assigned to the CHALICE rule is B2.

The **CATCH** rule was developed by Dr. Martin Osmond in the US in 2010 and was tested successfully for internal validity [51]. The rule was tested multiple times for external validity and proved externally valid in all the reported studies [48, 58–61, 63, 66, 72, 81]. The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to the CATCH rule is C1.

The **NEXUS II** rule was developed by Dr. William Mower in the US in 2005, primarily for the diagnosis of adult head injury [88, 89]. Later on, the rule was validated for paediatrics by Dr. Jennifer Oman in the US in 2006 [50]. The tool was then tested multiple times for external validity. One study failed to properly evaluate the rule after using a modified version, which did not show external validity [54]. Two studies proved the rule was externally valid for children less than 14 and 16 years [48, 85] and one study proved the rule was externally valid for children over 10 years [86]. Using the protocol, the mixed evidence here supports positive conclusion on external validity. The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to the NEXUS II rule is C1.

Palchak rule was developed by Dr. Michael Palchak and Dr. Nathan Kuppermann in the US in 2003 and was tested successfully for internal validity [52]. A study by the same authors in 2009 included validation of the rule in comparison to clinicians' judgement using the same dataset that was used for the rule development, so this is still considered an internal validation [87]. One external validation study reported the predictive performance of Palchak rule was acceptable [48]. The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Palchak rule is C2.

Haydel rule was developed by Dr. Micelle Haydel in the US in 2003 [47], **Atabaki** rule was developed by Dr. Shireen Atabaki in the US in 2008 [39], and **Buchanich** rule was developed by Dr. Jeanine Buchanich in the US in 2007 [40]. The three rules were tested successfully for internal validity. However, they were not tested for external validity; neither were they evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to these three rules is C3.

Da Dalt rule was developed by Dr. Liviana Da Dalt in Italy in 2006 [41], **Greenes** rule was developed by Dr. David Greenes in the US in 2001 [44, 45], and **Klemetti** rule was developed Dr. Sanna Klemetti in Finland in 2009 [48]. The studies conducted by these three researchers followed correct development methods for their proposed tools. However, the internal validation processes of the tools were not clearly reported. Accordingly, the final grade assigned to these three rules is C0.

Dr. Kimberly Quayle in the US in 1997 [53], **Dr. Ann Dietrich** in the US in 1993 [42], and **Dr. Ahmet Güzel** in Turkey in 2009 [46], each tried to develop a clinical prediction rule to identify children at low risk for traumatic brain injury after head trauma. Their studies discussed clinical risk factors, symptoms and signs that could reliably predict abnormalities in cranial computed tomography (CT) scans. Even though each used a different mix of common clinical variables, none of the three studies could demonstrate sufficient correlations between clinical variables, symptoms and signs of significant TBI and the later findings on CT.

Therefore, they could not produce predictive rules with sufficient internal validity. Accordingly, the final grade assigned to these three rules is C0. A summary of the results of grading the 14 paediatric head injury predictive tools, using the GRASP framework, is presented in Table 1. The GRASP framework detailed reports, of each of the 14 paediatric head injury predictive tools, are presented in Additional file 1: Tables S4 to S17.

Findings of the tools' analysis

The PECARN rule was the only tool evaluated in post-implementation impact studies. The PECARN and the CHALICE rules were evaluated for potential effect on healthcare, while the remaining 12 tools were only evaluated for predictive performance. Three of these 12 tools were externally validated; CATCH, NEXUS II, and Palchak rules, three were only internally validated; Haydel, Atabaki, and Buchanich rules, and the remaining six tools; Da Dalt, Greenes, Klemetti, Quayle, Dietrich, and Güzel rules did not show sufficient internal validity to be used in clinical practice.

Using statistical analysis, we explored possible correlations between different criteria of predictive tools and their evidence-based assigned grades. There is no correlation between the country of the tools' development and their assigned grades. For example, the 10 tools developed in the US include some of the highest and some of the lowest grades, so the country of a tool's development is not related to the grade of the tool. There is a weak correlation between the year of the tools' development and their assigned grades. The tools developed more recently could be higher in grade. There is a strong correlation between the number of citations of the tools, in the literature, and their assigned grades. The tools with higher citations are expected to be higher in grade. There is a very strong correlation between the number of studies discussing the tools and their assigned grades. The tools discussed and reported in more studies are higher in grade.

Table 1 Summary of Grading Paediatrics Head Injury Predictive Tools

Tool	Assigned Grade	Impact After Implementation			Planning for Implementation			Performance Before Implementation		
		Experimental Studies	Observational Studies	Subjective Studies	Potential Effect & Usability	Potential Effect	Usability	External Validation Multiple Times	External Validation Only Once	Internal Validation
		A1	A2	A3	B1	B2	B3	C1	C2	C3
PECARN (49)	A2		◕			●		●		●
CHALICE (43)	B2					◕		●		●
CATCH (51)	C1							●		●
NEXUS II (50, 54)	C1							◕		●
Palchak (52)	C2								●	●
Haydel (47)	C3									●
Atabaki (39)	C3									●
Buchanich (40)	C3									●
Da Dalt (41)	C0									○
Greenes (44, 45)	C0									○
Klemetti (48)	C0									○
Quayle (53)	C0									○
Dietrich (42)	C0									○
Güzel (46)	C0									○
Evidence Direction	● Positive Evidence				◕ Mixed Evidence Supporting Positive Conclusion					
	○ Negative Evidence				◔ Mixed Evidence Supporting Negative Conclusion					

To provide clinicians with a few more objective measures to compare the tools, in addition to the citations and the published studies, we developed three derived values; the citation index, the publication index, and the literature index. The PECARN, the CHALICE and the CATCH rules were cited in the literature 885, 309, and 319 times respectively. To make these figures comparable, we calculated the citation index as the average annual citations for each tool, by dividing the total citations of each tool by its age in years. Similarly, the publication index is the average annual studies discussing each tool. We also calculated a literature index; by multiplying the total number of citations by the total number of studies, on each tool, divided by 1000, for simplification. This figure reflects the post-implementation impact of each tool in the literature. Like the citations and publications, the three indices of the tools are strongly correlated with their assigned grades.

Looking at more detailed objective measures, reported in the development studies of the 14 paediatric head injury predictive tools; we find very interesting results. The predictive tools were developed using two main methodologies. Recursive partitioning was used to develop the PECARN, CHALICE, CATCH, NEXUS II, Palchak, Haydel, Atabaki, and Buchanich rules. Multivariate logistic regression analysis was used to develop Greenes, Da Dalt, Klemetti, Quayle, Dietrich and Güzel rules. In addition, many clinical variables were used in the development of the tools, such as altered mental status, amnesia, focal neurological signs, occurrence of seizure after injury, presence of skull fractures, loss of consciousness, history of headache and/or vomiting. The mix of clinical variables used, to build the tools' predictive models and their outcome scores, were similar but not the same for any of the tools. Moreover, the tools development studies used different paediatric populations and sample sizes. Consequently, the predictive performances of the tools, such as their sensitivities and specificities, were variable. Most of the tools showed high sensitivities, with the majority ranging from 90 to 100%, while their specificities were very different; ranging from 15 to 87%.

There is no correlation between the tools' development methodologies and their predictive performances. However, most of the tools developed using recursive partitioning showed relatively higher sensitivities but not necessarily better specificities. In addition, there is no correlation between the tools' development methodologies and their assigned grades. However, the six tools that used multivariate logistic regression analysis were all assigned grade C0; reporting no internal validity, while the other eight tools that used recursive partitioning showed higher variable grades. Furthermore, there is no correlation between the predictive performances of the tools and their assigned grades. For example, Da Dalt rule is assigned grade C0.

However, it has the highest sensitivity of 100% and the highest specificity of 87% among all the tools. This could be explained by the fact that Da Dalt rule was not internally validated, which makes it unqualified for external validation or implementation. While the CHALICE rule, which is assigned grade B2, has a sensitivity of 98% and a specificity of 86%, we find that the PECARN rule, which is the highest tool, assigned grade A2, has a similar sensitivity of 97% but lower specificity of 59%.

On the other hand, we find that there is a strong correlation between the size of the patient samples used in the development and internal validation studies of the tools and their assigned grades. The three main tools had the largest numbers of patients contributing to their development studies; 42,412 patients were enrolled and analysed to develop the PECARN rule, 22,772 to develop the CHALICE, and 3866 to develop the CATCH rule. The remaining 11 tools were developed using a relatively smaller number of patient samples, ranging from 3000 to only a hundred patients. In addition, there is a strong correlation between the number of researchers developing tools and their assigned grades. Two of the main three tools were developed by a large number of researchers; the PECARN rule was developed by 32 researchers and the CATCH rule was developed by 14 researchers. The remaining tools were developed by a relatively fewer number of researchers; ranging from 10 for the Palchak rule to only one researcher for the Buchanich rule.

Moreover, there is a correlation between the impact factor of the journal that published the development studies of the tools and their assigned grades. The PECARN rule, for example, was published in the Lancet, which is a highly ranked journal with an impact factor of 53.3. Furthermore, the three main tools; the PECARN, the CHALICE and the CATCH rules, in addition to the NEXUS II rule, were all supported by dedicated and well-funded research networks, programs, and professional groups, such as the Paediatric Emergency Care Applied Research Network for the PECARN rule, the Children's Head Injury Algorithm for the Prediction of Important Clinical Events study group for the CHALICE rule, the Paediatric Emergency Research Canada (PERC) Head Injury Study Group for the CATCH rule, and the National Emergency X-Radiography Utilization Study II for the NEXUS II rule. There is a correlation between being supported by dedicated research programs, as a tool, and having a higher assigned grade. A summary of tools' information, development studies indices, predictive performance and quality indicators of the 14 paediatric head injury predictive tools is presented in Table 2.

Additional file 1: Figure S3 shows the tools' distribution by their assigned grade. Additional file 1: Figure S4 distribution by country of development. Additional file 1: Figure S5 distribution by year of development. Additional file 1: Figure S6 number of citations of each tool. Additional file 1: Figure S7 number of studies reporting each tool. Additional file 1: Figure S8 size of patient samples used for development. Additional file 1: Figure S9 number of authors contributing to each tool. Additional file 1: Figure S10 the journal impact factor publishing each tool. Additional file 1: Figure S11 percentage of tools developed with/without dedicated support.

Discussion

This study presents a new evidence-based approach to grade and assess predictive tools. Based on the critical appraisal of the published evidence on predictive tools, the GRASP framework uses three dimensions to grade the tools: 1) phase of evaluation; before implementation, during planning for implementation and after implementation, 2) level of evidence; adding a numerical score within each phase, and 3) direction of evidence; positive, negative or mixed. The final grade is based on the highest phase of evaluation, supported by the highest level of positive evidence, or mixed evidence that supports a positive conclusion. Among the 14 paediatric head injury predictive tools, the PECARN rule stands out clearly, since it is the only tool evaluated in post-implementation impact studies, which needs some explanation.

The 14 predictive tools targeted variable paediatric age groups. Most of the tools focused on children less than 16 years of age. However, some tools extended their cover to less than 21 years, such as Atabaki, while others limited their population to children less than 2 or 3 years, such as Buchanich and Greenes. The tools used different development methodologies and their prediction models used different mix of clinical variables. Furthermore, the predictive performances of the tools, such as their sensitivities and specificities, were different. However, the predictive performances of the tools were not correlated with their assigned grades. This indicates that the technical specifications of the predictive tools did not, in the first place, influence their successful validation, acceptance, or implementation. The country and year of tools' development were also non-significantly influential on their successful path from validation into implementation. On the other hand, the number of citations of the studies, describing the development of the tools, and the number of studies reporting them are clearly correlated with tools' success. These two indicators are secondary to the main quality indicators of the tools' development studies, such as the sample size of patients used in the development of the tools and the number of researchers developing these tools.

In addition, the experiences of the researchers have an important role in leading better-quality studies. Three of

Table 2 Summary of tools' information, indices, predictive performance and quality

Tool	Tool Grade	Tool Information				Study Indices			Predictive Performance		Study Quality Indicators				
		Country	Year	Citations	Studies	Citation Index	Publication Index	Literature Index	Sensitivity	Specificity	Development Method	Patient Sample Size	Number of Authors	Journal Impact	Dedicated Support
PECARN [49]	A2	USA	2009	885	24	88.5	2.40	21.24	0.97	0.59	R	42,412	32	53.25	Yes
CHALICE [43]	B2	UK	2006	309	15	23.8	1.15	4.64	0.98	0.86	R	22,772	6	3.26	Yes
CATCH [51]	C1	USA	2006	319	12	24.5	0.92	3.83	0.98	0.50	R	3866	14	6.80	Yes
NEXUS II [50, 54]	C1	USA	2005	124	6	8.9	0.43	0.74	0.99	0.15	R	1666	8	5.70	Yes
Palchak [52]	C2	USA	2003	248	3	15.5	0.19	0.74	1.00	0.46	R	2043	10	5.35	No
Haydel [47]	C3	USA	2003	118	1	7.4	0.06	0.12	1.00	0.24	R	175	5	5.35	No
Atabaki [39]	C3	USA	2008	111	1	10.1	0.09	0.11	1.00	0.46	R	1000	8	5.73	No
Buchanich [40]	C3	USA	2007	4	1	0.3	0.08	0.00	1.00	0.40	R	97	1	1.00	No
Da Dalt [41]	C0	Italy	2006	85	1	6.5	0.08	0.09	1.00	0.87	M	3806	8	1.79	No
Greenes [44, 45]	C0	USA	1999	237	2	11.9	0.10	0.47	0.53	0.72	M	422	2	5.70	No
Klemetti [48]	C0	Finland	2009	18	1	1.8	0.10	0.02	0.94	0.29	M	485	4	1.07	No
Quayle [53]	C0	USA	1997	291	1	13.2	0.05	0.29	0.44	0.85	M	322	7	5.70	No
Dietrich [42]	C0	USA	1993	220	1	8.5	0.04	0.22	1.00	0.17	M	324	5	5.35	No
Güzel [46]	C0	Turkey	2009	17	1	1.7	0.10	0.02	0.69	0.43	M	916	6	1.00	No

Citation Index (Average Annual Citations) = (number of citations/age of development study), Publication Index (Average Annual Studies) = (number of studies/age of development study), Literature Index (Citations and Publications) = (number of citations X number of studies). Age of development study = (current year – year of tool's development). Development method: *R* Recursive Partitioning, *M* Multivariate Logistic Regression the researchers who developed the PECARN rule have already contributed to older but less successful tools. Before leading the team to develop the PECARN rule in 2009, Dr. Kuppermann contributed to developing the Quayle rule in 1997 and the Palchak rule in 2003. Dr. Quayle and Dr. Atabaki each developed her own rule in 1997 and 2008, before joining the team in developing the PECARN rule in 2009. The affiliations of the researchers, to highly ranked institutes, and the support of the studies by dedicated and well-funded research networks, programs, and professional groups, added to the credibility of the tools among clinicians and organisations. As a result of the better quality and higher credibility, the PECARN rule development study was published in a top ranked journal with a high impact factor; the Lancet. In addition, the three main tools; the PECARN, the CHALICE and the CATCH rules were endorsed by professional organisations and recommended in clinical practice guidelines, such as the paediatric head trauma clinical guidelines developed by the Royal Australian and New Zealand College of Radiologists [90].

Many studies compared paediatric head injury predictive tools. Among these, nine compared the three main tools; the PECARN, the CHALICE and the CATCH rules. Despite the fact that most of the studies reported PECARN as the highest quality tool, they reported that all three predictive tools had excellent sensitivities and performed well in assessing the outcome of clinically important TBI, suggesting that all were appropriate for use in assessing mild head injury in the ED [58, 91]. However, each tool is applicable to a different proportion of children with head injury. This makes the direct comparison of the three tools difficult [72]. The CHALICE rule applies to a broad population of head injuries of any severity, the PECARN rule was developed for minor head injuries only and the CATCH rule focused on a group of patients with specific signs or symptoms [59]. The PECARN rule is the most validated [37], and has the best sensitivity while the CHALICE rule has the best specificity [66, 91, 92]. Compared to senior, experienced, and high accuracy emergency physicians, the implementation of PECARN, CATCH or CHALICE rules have a potential to increase the CT rates with limited potential to increase the accuracy of detecting clinically important TBI [93]. In addition, the three tools were not more cost-effective than usual care in some ED settings [94]. Despite that CT is the imaging modality of choice in the ED, because of availability and speed, however, magnetic resonance imaging is recently becoming the preferred modality in children. This would change predictive tools' comparability and priority for recommendation, where further research is required [92].

Some predictive tools, in other clinical areas, gained their widespread acceptance and successful implementation by providing simplicity and feasibility. The Ottawa ankle and the Ottawa knee rules are good examples of simple paper based five items check lists, designed to exclude the need for an X-ray for possible bone fracture in adult patients at the ED [95, 96]. The resources needed to implement such tools are minimal; no technical requirements, special training or financial support are needed. Both tools were implemented, within 2 years of their development, and demonstrated positive post-implementation impact on the efficiency of ED healthcare services through wide scale high quality experimental studies [97–100].

Accordingly, selecting effective predictive tools remains a major challenge for most clinicians who usually lack the time and experience required to evaluate such tools; assessing their quality or grading their level of evidence, especially as their number and complexity have increased tremendously over the recent years. This is made worse by the complex nature of the evaluation process itself and the variability in the quality of published evidence. Furthermore, it is not always feasible to compare tools, even those designed for the same predictive tasks, due to the diversity of their development methodologies, clinical variables, target populations, conditioned applications, and predictive performances. Therefore, we chose not to look at the details of every single validation or implementation study. Alternatively, the GRASP framework provides users with a higher level and evidence-based approach to grade predictive tools through the critical appraisal of published evidence on their development and validation before implementation, usability and potential effect during planning for implementation, and post-implementation impact on clinical effectiveness, patient safety and healthcare efficiency. Based on the available evidence, the framework identifies tools that are more trusted by clinicians and researchers and consequently can be more successful. Using the GRASP framework might need some training for expert healthcare professionals and researchers, who are going to grade predictive tools and some awareness for end user clinicians who are going to use GRASP output to select predictive tools.

The main limitations of this study include the possibility of missing some predictive tools which could have been developed by clinicians but not yet published, because the GRASP framework depends on grading predictive tools based on their published evidence. Similarly, some of the published predictive tools could have been implemented in clinical practice but no studies, reporting their implementation or evaluating their post-implementation impact, have been published yet. Furthermore, while this study is in press or soon after it is published, an evidence on some tools may become available and could have an influence on the assigned grade.

Conclusion

Comparing the three main tools, which were assigned the highest GRASP grades PECARN, CHALICE and CATCH, to the remaining 11, we find that three main factors are highly crucial and indicate better tools. Firstly, the quality of the predictive tools, which is indicated by the development methodology of the tools, the patient sample size used for development, and the number of contributing authors. The quality is also reflected through the number of citations and number of studies discussing each tool. Secondly, the experience and credibility of the tools' authors, reflected in their clinical specialty and affiliated organisations. Thirdly, the support by dedicated and well-funded research programs. These three factors were more significantly influential, than the sole high predictive performance, on the wide acceptance and successful implementation of the tools. In addition, tools' simplicity and feasibility, in terms of resources needed, financial support, technical requirements, complexity and number of predictors, and training, are crucial factors of their success. It is important to select tools which best fit the intended tasks, the clinical conditions, the healthcare settings and the patient populations. Based on detailed specifications, a group of best predictive tools can be recommended for use in clinical practice. Through evidence-based grading of predictive tools, the GRASP framework confirmed the PECARN rule as the highest quality tool, compared to the other tools, which have variable levels of supporting evidence. The online availability of the GRASP framework will enable clinicians and clinical guideline developers to access detailed information, reported evidence and assigned grades of predictive tools. However, keeping such information up-to-date requires continuous updating of tools' reports when new evidence becomes available.

Additional file

Additional file 1: Figure S2. Searching the literature for predictive tools and related published evidence. **Figures S3 to S11.** Statistical figures describing the fourteen paediatric head injury clinical predictive tools. **Table S3.** The GRASP Framework Detailed Report template. **Tables S4 to S17.** The GRASP Framework Detailed Report on each of the fourteen paediatric head injury clinical predictive tools. (PDF 958 kb)

Abbreviations

CATCH: Canadian Assessment of Tomography for Childhood Head injury; CDC: Centers for Disease Control and Prevention; CDS: Clinical Decision Support; CHALICE: Children's Head injury ALgorithm for the prediction of Important Clinical Events; CINAHL: Cumulative Index to Nursing and Allied Health Literature; CT: Computed Tomography; ED: Emergency Department; EMBASE: Excerpta Medica Abstract Journals Database; GRASP: Grading and Assessment of Predictive Tools for Clinical Decision Support; MEDLINE: Medical Literature Analysis and Retrieval System Online; NEXUS: National Emergency X-Radiography Utilization Study; PECARN: Paediatric Emergency Care Applied Research Network; PERC: Paediatric Emergency Research Canada; TBI: Traumatic Brain Injury; US: United States

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Authors' contributions

MK was mainly responsible for the conception of the study and the detailed analysis of the tools. BG was responsible for the overall supervision of the work done, verification and validation of the analysis, results and discussion. The two authors have been involved in drafting the manuscript and revising it. Finally, the two authors gave approval of the manuscript to be published and agreed to be accountable for all aspects of the work.

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Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Ethics approval and consent to participate

No ethics approval was required for any element of this study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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100. Nichol G, Stiel IG, Wells GA, Juergensen LS, Laupacis A. An economic analysis of the Ottawa knee rule. Ann Emerg Med. 1999;34(4):438–47.

Publisher's Note

The Appendix

1. Searching the Literature for Predictive Tools and Related Published Evidence

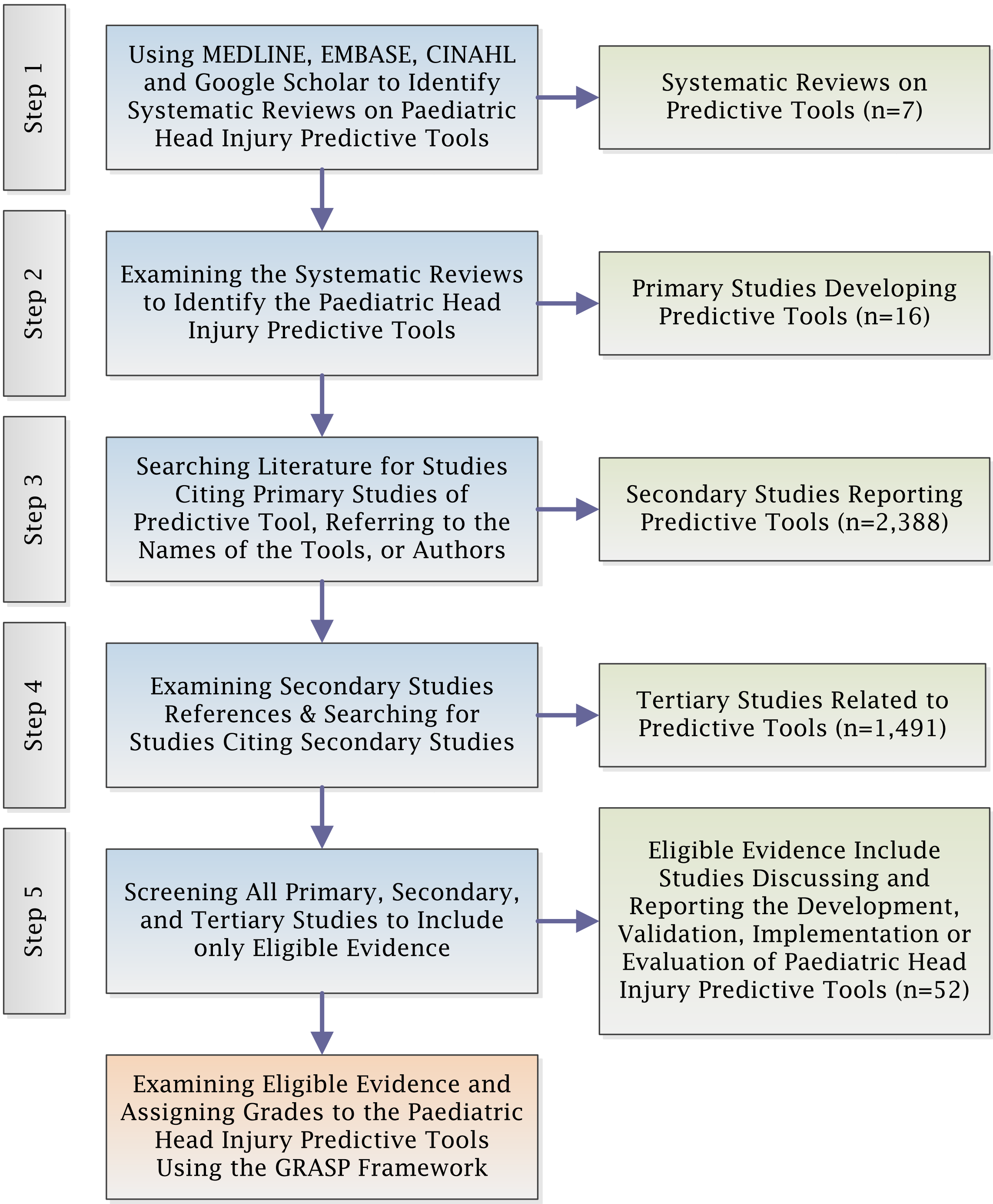

Figure 2: Searching the literature for paediatric head injury predictive tools and their related published evidence

2. Statistical Figures

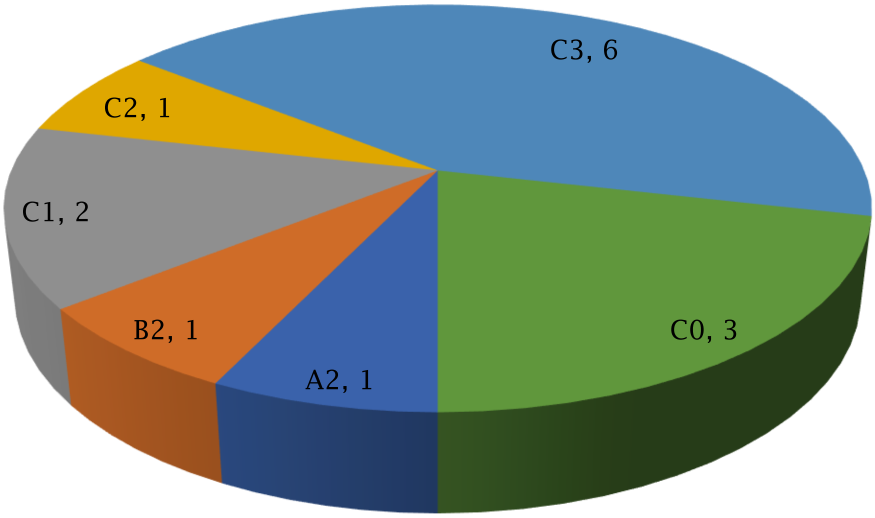

Figure 3: Tools distribution by their assigned grades
(Grade and number of tools)

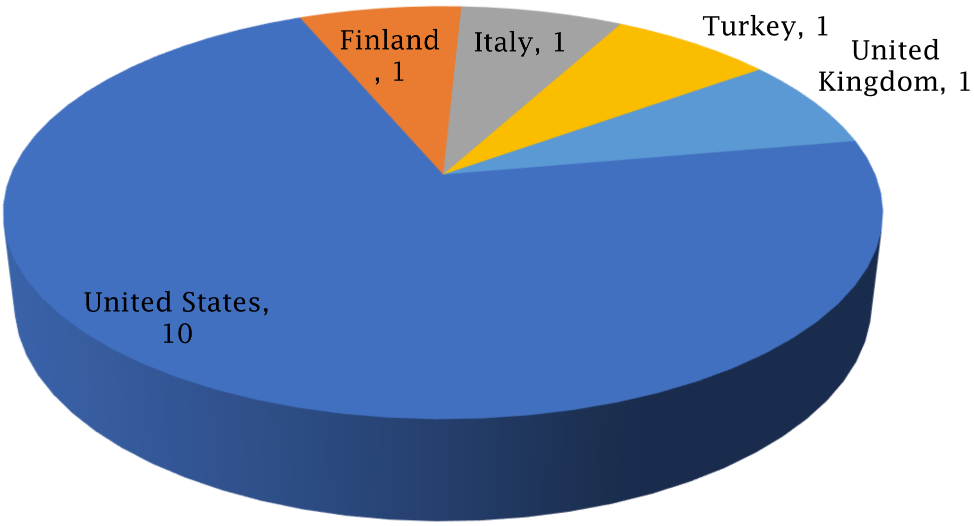

Figure 4: Tools distribution by their country of development
(Country and number of tools)

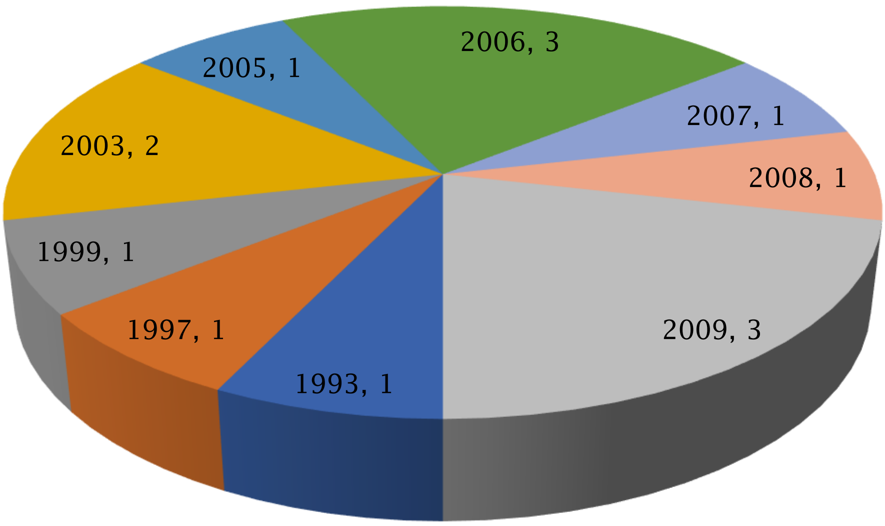

Figure 5: Tools distribution by their year of development
(Year and number of tools)

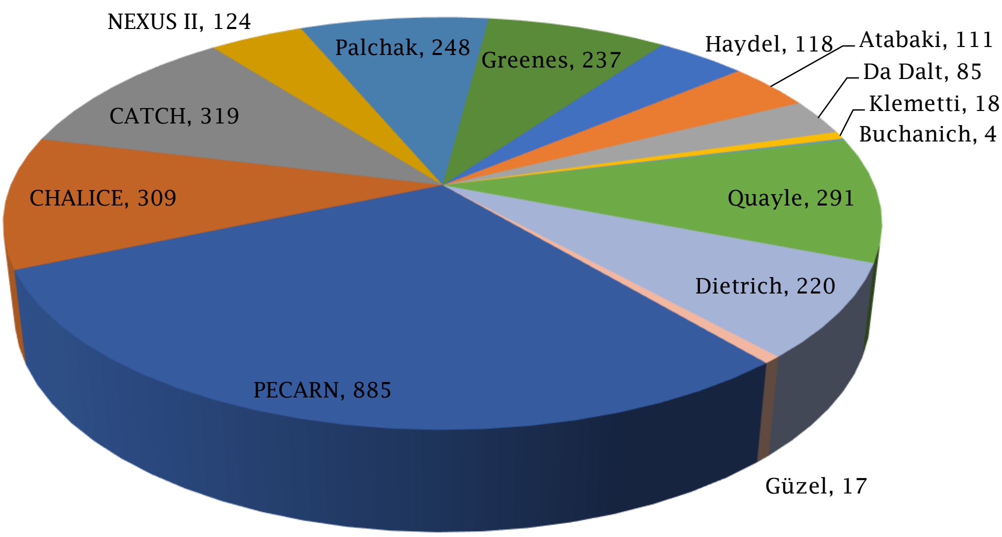

Figure 6: The number of citations of each tool

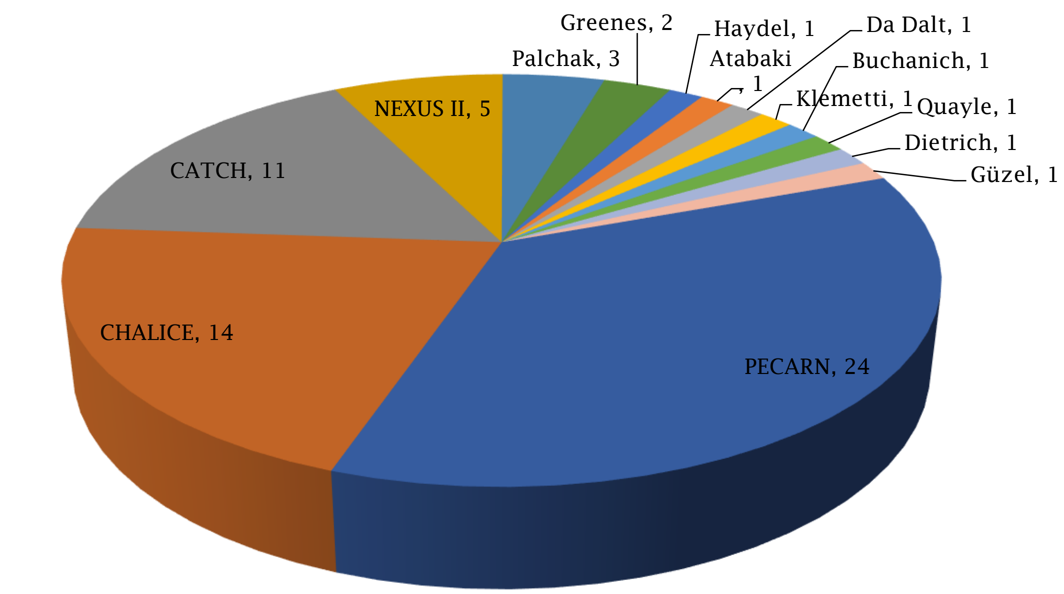

Figure 7: The number of studies reporting each tool

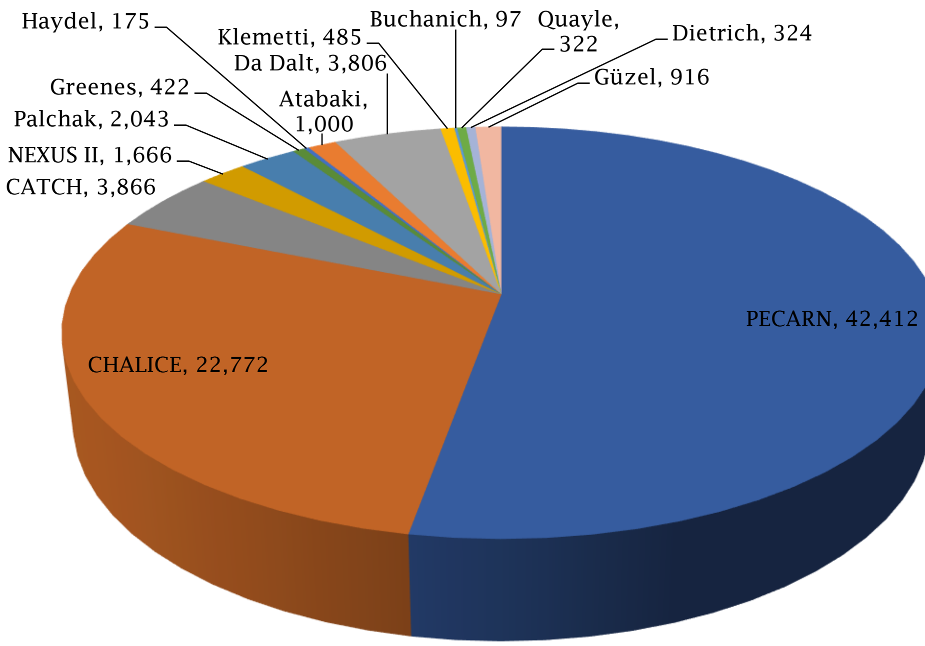

Figure 8: The size of patient samples used for developing each tool

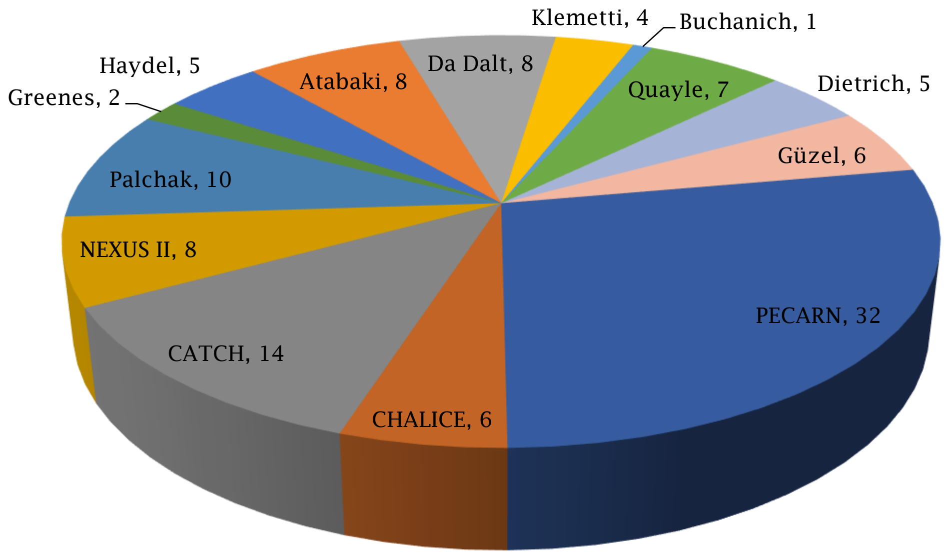

Figure 9: The number of authors contributing to the development of each tool

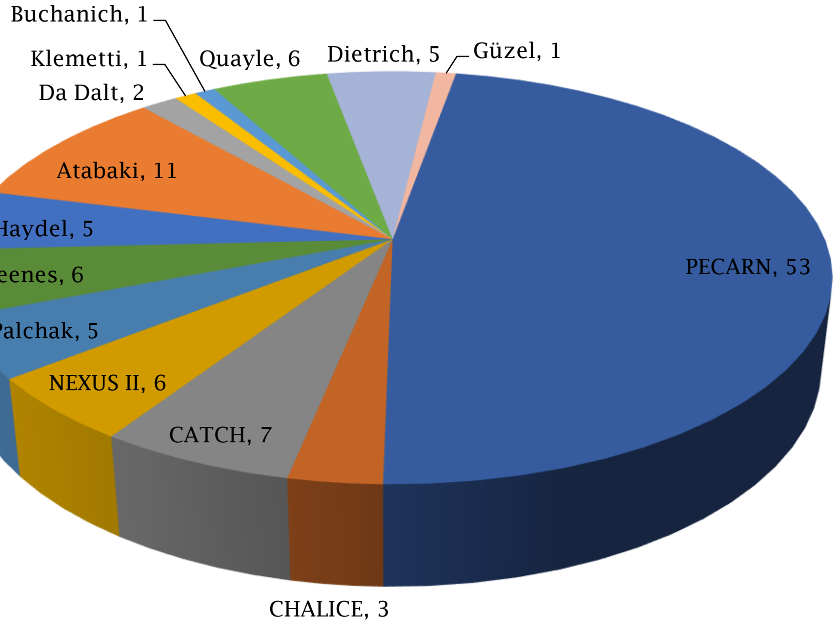

Figure 10: The journal impact factor publishing each tool

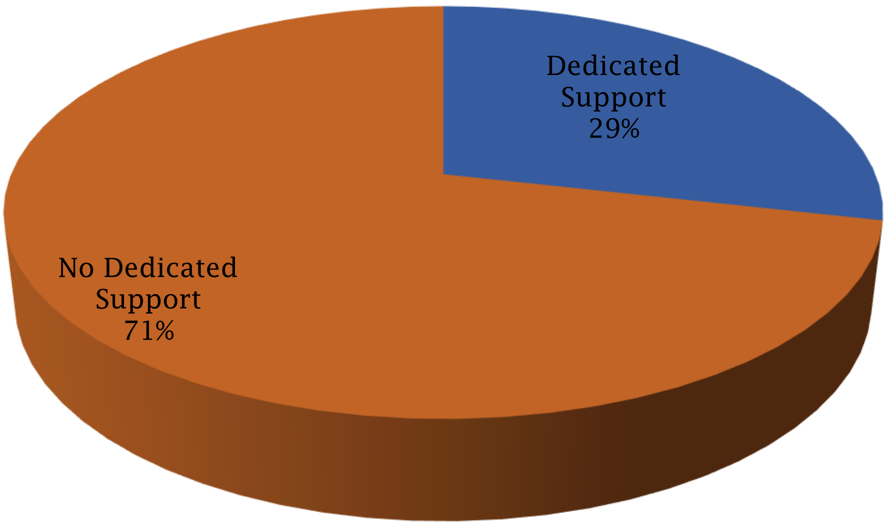

Figure 11: The percentage of tools developed with/without dedicated support

3. The GRASP Framework Detailed Report

Table 3: The GRASP Framework Detailed Report

Name	Name of predictive tool (report tool's creators and year in the absence of a given name)
Author	Name of developer (first author or researcher)
Country	Country of development
Year	Year of development
Category	Diagnostic/Therapeutic/Prognostic/Preventive
Intended use	Specific aim/intended use of the predictive tool
Intended user	Type of practitioner intended to use the tool
Clinical area	Clinical specialty
Target Population	Target patient population and health care settings in which the tool is applied
Target Outcome	Event to be predicted (including prediction lead time if needed)
Action	Recommended action based on tool's output
Input source	• Clinical (including Diagnostic, Genetic, Vital signs, Pathology) • Non-Clinical (including Healthcare Utilisation)
Input type	• Objective (Measured input; from electronic systems or clinical examination) • Subjective (Patient reported; history, checklist ...etc.)
Local context	Is the tool developed using location-specific data? (e.g. life expectancy tables)
Methodology	Type of algorithm used for developing the tool (e.g. parametric/non-parametric)
Internal Validation	Method of internal validation
Dedicated Support	Name of the supporting/funding research networks, programs, or professional groups
Endorsement	Organisations endorsing the tool and/or clinical guidelines recommending its utilisation
Automation Flag	Automation status (manual/automated)

Tool Citations	Total citations of the tool		
Studies	Number of studies reporting the tool		
Authors No	Number of authors		
Sample Size	Size of patient/record sample used in the development of the tool		
Journal Name	Name of the journal that published the tool's primary development study		
Journal Rank	Impact factor of the journal		
Citation Index	Calculated as: Average Annual Citations = number of citations/age of primary publication		
Publication Index	Calculated as: Average Annual Studies = number of studies/age of primary publication		
Literature Index	Calculated as: Citations and Publications = number of citations X number of studies		
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: **Before implementation** **Is it possible?**	Insufficient internal validation	**C0**	Not tested for internal validity, insufficiently internally validated, or internal validation was insufficiently reported.
	Internal validation	**C3**	Tested for internally validity (reported calibration & discrimination; sensitivity, specificity, positive and negative predictive values & other predictive performance measures).
	External validation	**C2**	Tested for external validity, using one external dataset.
	External validation multiple times	**C1**	Tested multiple times for external validity, using more than one external dataset.
Phase B: **Planning for implementation** **Is it practicable?**	Usability	**B3**	Reported usability testing (tool effectiveness, efficiency, satisfaction, learnability, memorability, and minimizing errors).
	Potential effect	**B2**	Reported estimated potential effect on clinical effectiveness, patient safety or healthcare efficiency.
	Potential effect & Usability	**B1**	Both potential effect and usability are reported.
Phase A: **After implementation:** **Is it desirable?**	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	Based on subjective studies; e.g. the opinion of a respected authority, clinical experience, a descriptive study, or a report of an expert committee or panel.
		A2	Based on observational studies; e.g. a well-designed cohort or case-control study.
		A1	Based on experimental studies; properly designed, widely applied randomised/nonrandomised controlled trial.
Assigned Grade	**Grade ABC/123**		**A1** **A2** **A3** **B1** **B2** **B3** **C1** **C2** **C3**
Direction of Evidence	● Positive Evidence		◕ Mixed Evidence Supporting Positive Conclusion
	○ Negative Evidence		◔ Mixed Evidence Supporting Negative Conclusion
Justification	Explains how the final grade is assigned based on evidence; which conclusions were taken into consideration, as positive evidence, and which were considered negative.		
References	Details of studies that support the justification: phase of evaluation, level of evidence, direction of evidence, study type, study settings, methodology, results, findings and conclusions (highlighted according to the findings codes).		
Findings Codes	Positive Findings / Negative Findings / Important Findings		

4. PECARN Rule – Grade A2

Table 4: The GRASP Framework Detailed Report of the PECARN Rule

Name	PECARN (Paediatric Emergency Care Applied Research Network) Head Injury/Trauma Rule		
Authors/Year	Dr. Nathan Kuppermann, United States, 2009		
Category	Diagnostic		
Intended use	Predicts need for brain imaging after paediatric head injury (Identify children who are at very low risk of clinically important brain injury).		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 18 years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Age < or > 2 years, GCS ≤14, altered mental status, palpable skull fracture, scalp haematoma, loss of consciousness, severe injury mechanism, severe headache and history of vomiting.		
Local context	Input does not depend on local context of data		
Methodology	Recursive partitioning		
Int. Validation	Cross validation + Separate validation population		
Dedicated Supp	Paediatric Emergency Care Applied Research Network, USA.		
Endorsement	Recommended by: • Paediatric Emergency Care Applied Research Network, a federally funded paediatric emergency medicine research network, United States. • Royal Australian & New Zealand College of Radiologists, 2015 for Paediatric Head Trauma https://www.ranzcr.com/documents/3839-print-version-paediatric-head-trauma/file		
Automation Flag	Manually used		
Tool Citations	885	Reported in 24 studies	
Authors	32	Sample Size = 42,412	
Journal Impact	53.3	The Lancet	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed and internally validated: • Kuppermann et al, 2009 (49)
	External validation	**C2**	Externally validated
	External validation multiple times	**C1**	Externally validated multiple times: • Ahmadi & Yousefifard, 2017 (Systematic Review) (55): ○ Fuller et al, 2012 (67) ○ Mihindu et al, 2014 (73) ○ Schonfeld et al, 2014 (76) ○ Easter et al, 2014 (66) ○ Lorton et al, 2016 (71) ○ Atabaki et al, 2016 (56) ○ Babl et al, 2017 (58) ○ Ide et al, 2017 (70) ○ Nakhjavan-Shahraki et al, 2017 (74) • Lyttle et al, 2013 (72) • Thiam, Yap & Chong, 2015 (77) • Babl & Bressan, 2015 (59) • Bozan et al, 2017 (63) • Babl et al, 2018 (61)
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Estimated potential effect: • Holmes et al, 2013 (69) • Nishijima et al, 2015 (75)

			• Barrett, 2016 (62) • Gökharman et al, 2017 (68)
	Potential effect & Usability	**B1**	Not Applicable
Phase A: **After implementation:** **Is the tool desirable?**	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	Observational studies – negative conclusions: • Bressan et al, 2015 (65) Observational studies – positive conclusions: • Bressan et al, 2012 (64) • Atabaki et al, 2017 (57)
		A1	No experimental studies are reported
Assigned Grade	**Grade A2**		A1 | ◔ | A3 | B1 | ● | B3 | ● | C2 | ●
Justification	The PECARN rule was developed in 2009 and tested successfully for internal validity (49). The rule was tested fifteen times for external validity and proved externally valid in all the reported studies (56, 58-61, 63, 66, 67, 70-74, 76, 77). This qualifies the PECARN rule for grade C1. Four economic analysis studies discussed the positive potential effects of using the PECARN rule on lowering healthcare costs, decreasing frequency of CT scans and minimising exposure of children to harmful ionising radiation (62, 68, 69, 75). This qualifies the PECARN rule for grade B2. Three observational pre-and-post-implementation impact studies were conducted. One study concluded that the PECARN intermediate-risk predictors did not play a major role in the physicians' decision to perform a CT scan (65). However, the other two studies concluded that implementing and using the PECARN rule was associated with a statistically significant decrease in CT utilisation without safety or effectiveness problems (57, 64). Using the protocol, the mixed evidence here supports positive conclusion on the post-implementation impact of the PECARN rule. Accordingly, the final grade assigned to the PECARN rule is A2.		

References	Development and Internal Validation:
	
	• Kuppermann, N., Holmes, J. F., Dayan, P. S., Hoyle, J. D., Atabaki, S. M., Holubkov, R., ... & Badawy, M. K. (2009). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. The Lancet, 374(9696), 1160-1170.
	
	External Validation:
	
	• Ahmadi, S., & Yousefifard, M. (2017). Accuracy of Pediatric Emergency Care Applied Research Network Rules in Prediction of Clinically Important Head Injuries; A Systematic Review and Meta-Analysis. International Journal of Pediatrics, 5(12), 6285-6300. **Results:** Data from 10 studies were included in this meta-analysis. Area under the curve of SROC for PECARN model in prediction of ciTBI in children younger than 2 years old was 0.85 (95% CI: 0.82-0.88). Sensitivity, specificity and diagnostic odds ratio of this model were also calculated to be 0.98 (95% CI: 0.92-1.0), 0.56 (95% CI: 0.48-0.64) and 82.53 (95% CI: 16.23-419.63), respectively. AUC of SROC for this model in prediction of ciTBI in children aged 2-18 years old was also found to be 0.97 (95% CI: 0.95-0.98) with a sensitivity, specificity and diagnostic odds ratio of 0.98 (95% CI: 0.95-0.99), 0.60 (95% CI: 0.53-0.67) and 80.73 (95% CI: 30.59-213.05). **Conclusion:** The findings of this study are indicative of a high screening value for PECARN model in prediction of ciTBI and classification of patients. So it is recommended that the decision rule be used in routine practice for children referring with mild traumatic brain injuries.
	
	  ◦ Fuller, G., Dunning, J., Batchelor, J., & Lecky, F. (2012, April). An External Validation of the PECARN Clinical Decision Rule for CT Head Imaging of Infants with Minor Head Injury. In BRAIN INJURY (Vol. 26, No. 4-5, pp. 429-430). TELEPHONE HOUSE, 69-77 PAUL STREET, LONDON EC2A 4LQ, ENGLAND: INFORMA HEALTHCARE.
	
	  ◦ Mihindu, E., Bhullar, I., Tepas, J., & Kerwin, A. (2014). Computed tomography of the head in children with mild traumatic brain injury. The American surgeon, 80(9), 841-843.
	
	  ◦ Schonfeld, D., Bressan, S., Da Dalt, L., Henien, M. N., Winnett, J. A., & Nigrovic, L. E. (2014). Pediatric Emergency Care Applied Research Network head injury clinical prediction rules are reliable in practice. Archives of disease in childhood, archdischild-2013.
	
	  ◦ Easter, J. S., Bakes, K., Dhaliwal, J., Miller, M., Caruso, E., & Haukoos, J. S. (2014). Comparison of PECARN, CATCH, and CHALICE rules for children		

with minor head injury: a prospective cohort study. Annals of emergency medicine, 64(2), 145-152.

  - Lorton, F., Poullaouec, C., Legallais, E., Simon-Pimmel, J., Chêne, M. A., Leroy, H., ... & Gras-Le Guen, C. (2016). Validation of the PECARN clinical decision rule for children with minor head trauma: a French multicenter prospective study. Scandinavian journal of trauma, resuscitation and emergency medicine, 24(1), 98.

  - Atabaki, S. M., Hoyle Jr, J. D., Schunk, J. E., Monroe, D. J., Alpern, E. R., Quayle, K. S., ... & Dayan, P. S. (2016). Comparison of prediction rules and clinician suspicion for identifying children with clinically important brain injuries after blunt head trauma. Academic emergency medicine, 23(5), 566-575.

  - Babl, F. E., Borland, M. L., Phillips, N., Kochar, A., Dalton, S., McCaskill, M., ... & Lyttle, M. D. (2017). Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. The Lancet.

  - Ide, K., Uematsu, S., Tetsuhara, K., Yoshimura, S., Kato, T., & Kobayashi, T. (2017). External Validation of the PECARN Head Trauma Prediction Rules in Japan. Academic Emergency Medicine, 24(3), 308-314.

  - Nakhjavan-Shahraki, B., Yousefifard, M., Hajighanbari, M. J., Oraii, A., Safari, S., & Hosseini, M. (2017). Pediatric Emergency Care Applied Research Network (PECARN) prediction rules in identifying high risk children with mild traumatic brain injury. European journal of trauma and emergency surgery, 43(6), 755-762.

- Lyttle, M. D., Cheek, J. A., Blackburn, C., Oakley, E., Ward, B., Fry, A., ... & Babl, F. E. (2013). Applicability of the CATCH, CHALICE and PECARN paediatric head injury clinical decision rules: pilot data from a single Australian centre. Emerg Med J, 30(10), 790-794. 1,012 patients (69.9%) were enrolled with 949 available for analysis. Mean age was 6.8 years (21% <2 years). 95% had initial Glasgow Coma Scale 15. CT rate was 12.8% and neurosurgery rate was 0.7%. No CDR was applicable to all patients. CHALICE was applicable to the most (97%, 95% CI 96% to 98%) and CATCH to the fewest (26%, 95% CI 24% to 29%). PECARN was applicable to 76% (95% CI 70% to 82%) aged <2 years, and 74% (95% CI 71% to 77%) aged 2–<18 years.

- Babl, F. E., & Bressan, S. (2015). Physician practice and PECARN rule outperform CATCH and CHALICE rules based on the detection of traumatic brain injury as defined by PECARN. Evidence-based medicine, 20(1), 33-34. In 1009 children, 21 had ciTBI. All were identified by the PECARN rule and physician practice. Ranked **sensitivities** were as follows: physician practice and **PECARN 100%** (95% CI 84% to 100%), physician estimates 95% (95% CI 76% to 100%), CATCH 91% (95% CI 70% to 99%) and CHALICE 84% (95% CI 60% to 97%). Ranked **specificities** were: CHALICE 85% (95% CI 82% to 87%), physician estimates 68% (95% CI 65% to 71%), **PECARN 62%** (95% CI 59% to 66%), physician practice 50% (95% CI 47% to 53%), and CATCH 44% (95% CI 41% to 47%). **Secondary outcomes included need for neurosurgical intervention with sensitivities of 100% for PECARN and physician practice** and 75% for CATCH and CHALICE.

- Thiam, D. W., Yap, S. H., & Chong, S. L. (2015). Clinical decision rules for paediatric minor head injury: are CT scans a necessary evil. Ann Acad Med Singap, 44, 335-41. The CDRs demonstrated **sensitivities** of: CATCH 100% (54.1 to 100), CHALICE 83.3% (35.9 to 99.6), **PECARN 100%** (54.1 to 100), and **specificities** of: CATCH 80.3% (77.9 to 82.5), CHALICE 76.4% (73.8 to 78.8), **PECARN high- and intermediate-risk 61.6%** (58.8 to 64.4) and **PECARN high-risk only 96.7%** (95.5 to 97.6). Conclusion: The CDRs demonstrated high accuracy in detecting children with positive CT fi ndings but direct application in areas with low rates of signifi cant traumatic brain injury (TBI) is likely to increase unnecessary CT scans ordered. Clinical observation in most cases may be a better alternative.

- Bozan, Ö., Aksel, G., Kahraman, H. A., Giritli, Ö., & Eroğlu, S. E. (2017). Comparison of PECARN and CATCH clinical decision rules in children with minor blunt head trauma. European Journal of Trauma and Emergency Surgery, 1-7. The sensitivity of PECARN was 95 (95% CI 72–100%) and specificity was 53 (95% CI 47–60%), while the sensitivity of CATCH was 48 (95% CI 25–71%) and specificity was 83 (95% CI 79–88%).

- Babl, F. E., Oakley, E., Dalziel, S. R., Borland, M. L., Phillips, N., Kochar, A., ... & Neutze, J. (2018). Accuracy of clinician practice compared with three head injury decision rules in children: a prospective cohort study. Annals of emergency medicine, 71(6),

	703-710. Clinician identification of clinically important traumatic brain injury based on CT performed had a sensitivity of 158 of 160, or 98.8% (95% confidence interval [CI] 95.6% to 99.8%) and a specificity of 17,332 of 18,753, or 92.4% (95% CI 92.0% to 92.8%). **Sensitivity of PECARN for children younger than 2 years was 42 of 42 (100.0%; 95% CI 91.6% to 100.0%), and for those 2 years and older, it was 117 of 118 (99.2%; 95% CI 95.4% to 100.0%)**; for CATCH (high/medium risk), it was 147 of 160 (91.9%; 95% CI 86.5% to 95.6%); and for CHALICE, 148 of 160 (92.5%; 95% CI 87.3% to 96.1%). Conclusion: In a setting with high clinician accuracy and a low CT rate, PECARN, CATCH, or CHALICE clinical decision rules have limited potential to increase the accuracy of detecting clinically important traumat c brain injury and may increase the CT rate. In this prospective multicenter study of 18,913 children with mild head injury, clinical judgment demonstrated sensitivity similar to that of any of the 3 decision rules, as well as higher specificity than any of them. In these nationalized health care settings, clinical decision rules for paediatric head injury did not improve on clinical judgment and would likely increase CT use. Potential Effect: • Nishijima, D. K., Yang, Z., Urbich, M., Holmes, J. F., Zwienenberg-Lee, M., Melnikow, J., & Kuppermann, N. (2015). Cost-effectiveness of the PECARN rule in children with minor head trauma. Annals of emergency medicine, 65(1), 72-80. (PECARN strategy used fewer cranial CT scans (274 versus 353), resulted in fewer radiation-induced cancers (0.34 versus 0.45), cost less ($904,940 versus $954,420), and had lower net quality-adjusted life-year loss (-4.64 versus -5.79). PECARN strategy is more effective and less costly than usual care). • Gökharman, F. D., AYDIN, S., Fatihoğlu, E., & KOŞAR, P. N. (2017). Pediatric Emergency Care Applied Research Network head injury prediction rules: on the basis of cost and effectiveness. Turkish journal of medical sciences, 47(6), 1770-1777. (Thus, following the PECARN rule, the treatment of 825 (79.2%) patients could be managed without cranial CT. It can be inferred from the data that unnecessary cranial CT imaging entailed a cost of approximately US $13,750–16,500 and a total X-ray dose of 1650–2062 mSv). • Barrett, J. (2016). The Use of Clinical Decision Rules to Reduce Unnecessary Head CT Scans in Pediatric Populations (Doctoral dissertation, The University of Arizona.). (Both the CHALICE and PECARN CDRs have the potential to reduce scan rates in our home institution. The CHALICE CDR would have resulted in a greater reduction in CT scans. PECARN also would have reduced the number of scans in children 2 years and older, but not in children <2 years old). • Holmes, M. W., Goodacre, S., Stevenson, M. D., Pandor, A., & Pickering, A. (2013). The cost-effectiveness of diagnostic management strategies for children with minor head injury. Archives of disease in childhood, 98(12), 939-944. (Our economic analysis confirms that the use of CT scanning as determined by a clinical decision rule is a cost-effective use of healthcare resources for paediatric patients). Implementation: • Bressan, S., Romanato, S., Mion, T., Zanconato, S., & Da Dalt, L. (2012). Implementation of adapted PECARN decision rule for children with minor head injury in the pediatric emergency department. Academic Emergency Medicine, 19(7), 801-807. (PECARN rule was successfully implemented, achieving high adherence and satisfaction of medical staff. Its use determined a low CT scan rate that was unchanged compared to previous clinical practice and showed an optimal safety and high efficacy profile. Strict monitoring is mandatory to evaluate the long-lasting benefit in patient care and/or resource utilization). • Bressan, S., Steiner, I. P., Mion, T., Berlese, P., Romanato, S., & Da Dalt, L. (2015). The Pediatric Emergency Care Applied Research Network intermediate-risk predictors were not associated with scanning decisions for minor head injuries. Acta paediatrica, 104(1), 47-52. (The PECARN intermediate-risk predictors did not play a major role in the decision to perform a CT scan. The only factor significantly associated with the decision to perform a CT scan was when the patient was younger than 3 months of age). • Atabaki, S. M., Jacobs, B. R., Brown, K. M., Shahzeidi, S., Heard-Garris, N. J., Chamberlain, M. B., ... & Chamberlain, J. M. (2017). Quality Improvement in Pediatric Head Trauma with PECARN rule Implementation as Computerized Decision Support. Pediatric Quality & Safety, 2(3), e019. (Statistical process control charts confirmed decreased CT rates over time POST that was not present PRE. Secondary statistical analyses confirmed that CT scan utilization rates decreased from 26.8% to 18.9%

	(unadjusted Odds Ratio [OR], 0.64; 95% Confidence Interval [CI], 0.53 -0.76; adjusted OR, 0.71; 95% CI, 0.58 -0.86). Length of stay was unchanged. There was no increase in returns within 7 days and no significant missed diagnoses). Additional Commentary and Reviews: • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718. • Lyttle, M. D., Crowe, L., Oakley, E., Dunning, J., & Babl, F. E. (2012). Comparing CATCH, CHALICE and PECARN clinical decision rules for paediatric head injuries. Emerg Med J, emermed-2011.
Colour Code	• Important Findings • Less Relevant Findings • Positive Findings • Negative Findings

5. CHALICE Rule – Grade B2

Table 5: The GRASP Framework Detailed Report of the CHALICE Rule

Name	CHALICE (Children's Head injury ALgorithm for the prediction of Important Clinical Events) Rule	
Authors/Year	Dr. Joel Dunning, United Kingdom, 2006	
Category	Diagnostic	
Intended use	Predicts death, need for neurosurgical intervention or CT abnormality in children with head trauma	
Intended user	Physicians	
Clinical area	Emergency department (ED)	
Target Population	Children less than 16 years of age at ED for head trauma	
Target Outcome	Traumatic brain injury	
Action	Do/Do Not Consider CT + Acute intervention	
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)	
Input type	Clinical data (History, Examination, and Mechanism of Injury)	
Local context	Input does not depend on local context of data	
Methodology	Recursive partitioning	
Int. Validation	Cross validation	
Dedicated Supp	Children's Head Injury Algorithm for the Prediction of Important Clinical Events Study Group, UK	
Endorsement	Recommended by: • NICE Guidelines 2014 (Paediatrics) - The National Institute for Health and Care Excellence, UK (https://www.nice.org.uk/guidance/cg176/evidence/full-guideline-191719837) • Royal Australian & New Zealand College of Radiologists, 2015 for Paediatric Head Trauma https://www.ranzcr.com/documents/3839-print-version-paediatric-head-trauma/file	
Automation Flag	Manually used	
Tool Citations	309	Reported in 15 studies

<table>
<tr><td>Authors</td><td>6</td><td colspan="10">Sample Size = 22,772</td></tr>
<tr><td>Journal Impact</td><td>3.26</td><td colspan="10">Archives of disease in childhood</td></tr>
<tr><td>Phase of Evaluation</td><td>Level of Evidence</td><td>Grade</td><td colspan="9">Evaluation Studies</td></tr>
<tr><td rowspan="3">Phase C:
Before implementation
Does the tool work? Is it possible?</td><td>Internal validation</td><td>C3</td><td colspan="9">Developed and internally validated:
• Dunning et al, 2006 (43)</td></tr>
<tr><td>External validation</td><td>C2</td><td colspan="9">Externally validated</td></tr>
<tr><td>External validation multiple times</td><td>C1</td><td colspan="9">Externally validated multiple times:
• Klemetti et al, 2009 (48)
• Lyttle et al, 2013 (72)
• Easter et al, 2014 (66)
• Thiam, Yap & Chong, 2015 (77)
• Babl et al, 2014 (60)
• Babl & Bressan, 2015 (59)
• Babl et al, 2017 (58)
• Babl et al, 2018 (61)</td></tr>
<tr><td rowspan="3">Phase B:
Planning for implementation:
Is the tool practicable?</td><td>Usability</td><td>B3</td><td colspan="9">Not reported</td></tr>
<tr><td>Potential effect</td><td>B2</td><td colspan="9">Estimated potential effect – negative conclusions:
• Crowe, Anderson & Babl, 2010 (79)
• Harty & Bellis, 2010 (80)

Estimated potential effect – positive conclusions:
• Pandor et al, 2011 (24)
• Holmes et al, 2013 (69)
• Alali et al, 2015 (78)
• Barrett, 2016 (62)</td></tr>
<tr><td>Potential effect & Usability</td><td>B1</td><td colspan="9">Not Applicable</td></tr>
<tr><td rowspan="3">Phase A:
After implementation:
Is the tool desirable?</td><td rowspan="3">Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency</td><td>A3</td><td colspan="9">No subjective studies are reported</td></tr>
<tr><td>A2</td><td colspan="9">No observational studies are reported</td></tr>
<tr><td>A1</td><td colspan="9">No experimental studies are reported</td></tr>
<tr><td>Assigned Grade</td><td colspan="2">Grade B2</td><td>A1</td><td>A2</td><td>A3</td><td>B1</td><td>◔</td><td>B3</td><td>●</td><td>C2</td><td>●</td></tr>
<tr><td>Justification</td><td colspan="11">The CHALICE rule was developed in 2006 and tested successfully for internal validity (43). The rule was tested seven times for external validity and proved externally valid in all the reported studies (48, 58-60, 66, 72, 77). This qualifies the CHALICE rule for grade C1. Six cost-effectiveness studies discussed the potential effects of implementing the rule; whether it would increase or decrease the number and cost of CT scans and its potential effect on exposure of children to radiation. Two of the six studies in 2010 reported that the implementation of CHALICE rule would increase the number of CT scans performed and increase the exposure of children to radiation (79, 80). However, four subsequent studies in 2011, 2013, 2015 and 2016 reported that implementing the rule would be a cost-effective strategy to safely reduce unnecessary head CT scans (24, 62, 69, 78). Using the protocol, the mixed evidence here supports positive conclusion on the cost-effectiveness and potential effects of implementing the CHALICE rule. The rule was not evaluated for usability or post-implementation impact. Accordingly, the final grade assigned to the CHALICE rule is B2.</td></tr>
<tr><td>References</td><td colspan="11">Development and Internal Validation:

• Dunning, J., Daly, J. P., Lomas, J. P., Lecky, F., Batchelor, J., & Mackway-Jones, K. (2006). Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. Archives of disease in childhood, 91(11), 885-891.

External Validation:

• Klemetti, S., Uhari, M., Pokka, T., & Rantala, H. (2009). Evaluation of decision rules for identifying serious consequences of traumatic head injuries in pediatric patients. Pediatric emergency care, 25(12), 811-815.

• Lyttle, M. D., Cheek, J. A., Blackburn, C., Oakley, E., Ward, B., Fry, A., ... & Babl, F. E. (2013). Applicability of the CATCH, CHALICE and PECARN paediatric head injury clinical decision rules: pilot data from a single Australian centre. Emerg Med J, 30(10), 790-794.</td></tr>
</table>

- Easter, J. S., Bakes, K., Dhaliwal, J., Miller, M., Caruso, E., & Haukoos, J. S. (2014). Comparison of PECARN, CATCH, and CHALICE rules for children with minor head injury: a prospective cohort study. Annals of emergency medicine, 64(2), 145-152.

- Thiam, D. W., Yap, S. H., & Chong, S. L. (2015). Clinical decision rules for paediatric minor head injury: are CT scans a necessary evil. Ann Acad Med Singap, 44, 335-41.

- Babl, F. E., Lyttle, M. D., Bressan, S., Borland, M., Phillips, N., Kochar, A., ... & Gilhotra, Y. (2014). A prospective observational study to assess the diagnostic accuracy of clinical decision rules for children presenting to emergency departments after head injuries (protocol): the Australasian Paediatric Head Injury Rules Study (APHIRST). BMC pediatrics, 14(1), 148.

- Babl, F. E., & Bressan, S. (2015). Physician practice and PECARN rule outperform CATCH and CHALICE rules based on the detection of traumatic brain injury as defined by PECARN. Evidence-based medicine, 20(1), 33-34.

- Babl, F. E., Borland, M. L., Phillips, N., Kochar, A., Dalton, S., McCaskill, M., ... & Lyttle, M. D. (2017). Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. The Lancet.

- Babl, F. E., Oakley, E., Dalziel, S. R., Borland, M. L., Phillips, N., Kochar, A., ... & Neutze, J. (2018). Accuracy of clinician practice compared with three head injury decision rules in children: a prospective cohort study. Annals of emergency medicine, 71(6), 703-710.

Potential Effect (Negative conclusions):

- Crowe, L., Anderson, V., & Babl, F. E. (2010). Application of the CHALICE clinical prediction rule for intracranial injury in children outside the UK: impact on head CT rate. Archives of disease in childhood, archdischild174854. (Implementation of the CHALICE clinical prediction rule would cause an increase in the number of CT scans. Although the CHALICE rule would have identified a very small number of additional cases with abnormal CT scans, based on our clinical set-up the majority of CT scans would have been unnecessary with resultant radiation exposure and the possible need for sedation of the child. The value of the CHALICE rule is acknowledged, but the role of expectant observation and senior staff review needs to be clarified).

- Harty, E., & Bellis, F. (2010). CHALICE head injury rule: an implementation study. Emergency medicine journal, emj-2009. (If the pre-existing (2003) guideline had been strictly applied, 28 (6%) of the 464 patients analysed would have received a computed tomography (CT) scan. Applying the 2007 guideline (based on CHALICE head injury rule) to the same 464 patients resulted in an extra 21 (4.6%) scans).

Potential Effect (Positive conclusions):

- Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. (The CHALICE rule was the most cost-effective strategy when derivation data were used, but the NEXUS II rule was optimal where validation data were used).

- Holmes, M. W., Goodacre, S., Stevenson, M. D., Pandor, A., & Pickering, A. (2013). The cost-effectiveness of diagnostic management strategies for children with minor head injury. Archives of disease in childhood, 98(12), 939-944. (Our economic analysis confirms that the use of CT scanning as determined by a clinical decision rule is a cost-effective use of healthcare resources for paediatric patients).

- Alali, A. S., Burton, K., Fowler, R. A., Naimark, D. M., Scales, D. C., Mainprize, T. G., & Nathens, A. B. (2015). Economic evaluations in the diagnosis and management of traumatic brain injury: a systematic review and analysis of quality. Value in Health, 18(5), 721-734. (Current evidence from high-quality studies supports the economic attractiveness of a low medical threshold for CT scanning of asymptomatic infants with possible inflicted TBI, the utilization of the Canadian CT Head Rule in adults and the CHALICE rule in children as the diagnostic strategies for mild TBI).

- Barrett, J. (2016). The Use of Clinical Decision Rules to Reduce Unnecessary Head CT Scans in Pediatric Populations (Doctoral dissertation, The University of Arizona.). (Both the CHALICE and PECARN CDRs have the potential to reduce scan rates in our home institution. The CHALICE CDR would have resulted in a greater reduction in CT

	scans. PECARN also would have reduced the number of scans in children 2 years and older, but not in children <2 years old). Additional Commentary and Reviews: • Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154. • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718. • Lyttle, M. D., Crowe, L., Oakley, E., Dunning, J., & Babl, F. E. (2012). Comparing CATCH, CHALICE and PECARN clinical decision rules for paediatric head injuries. Emerg Med J, emermed-2011. • Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).
Colour Code	• Important Findings • Less Relevant Findings • Positive Findings • Negative Findings

6. CATCH Rule – Grade C1

Table 6: The GRASP Framework Detailed Report of the CATCH Rule

Name	CATCH Rule (Canadian Assessment of Tomography for Childhood Head injury)
Authors/Year	Dr. Martin Osmond, United States, 2010
Category	Diagnostic
Intended use	Predicts clinically significant head injuries in children after minor head trauma
Intended user	Physicians
Clinical area	Emergency department (ED)
Target Population	Children less than 16 years of age at ED for head trauma
Target Outcome	Traumatic brain injury
Action	Do/Do Not Consider CT + Acute intervention
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)
Input type	Clinical data: GCS <15 at 2 hrs after injury, suspected open or depressed skull fracture, history of worsening headache, irritability on exam, any sign of basal skull fracture (hemotympanum, raccoon eyes, CSF otorrhea or rhinorrhoea, Battle's sign), large boggy scalp hematoma, dangerous mechanism of injury (MVC, fall from ≥3 ft (91 cm) or 5 stairs, fall from bicycle with no helmet).
Local context	Input does not depend on local context of data
Methodology	Recursive partitioning
Int. Validation	Bootstrapping method

Dedicated Supp	Paediatric Emergency Research Canada (PERC) Head Injury Study Group, Canada		
Endorsement	Recommended by the Royal Australian & New Zealand College of Radiologists, 2015 for Paediatric Head Trauma: https://www.ranzcr.com/documents/3839-print-version-paediatric-head-trauma/file		
Automation Flag	Manually used		
Tool Citations	319	Reported in 12 studies	
Authors	14	Sample Size = 3,866	
Journal Impact	6.8	Canadian Medical Association Journal	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed and internally validated: • Osmond & Stiell, 2002 (82) • Osmond et al, 2006 (83) • Osmond et al, 2010 (51)
	External validation	**C2**	Externally validated
	External validation multiple times	**C1**	Externally validated multiple times: • Gerdung, Dowling & Lang, 2012 (81) • Klement et al, 2012 (48) • Lyttle et al, 2013 (72) • Easter et al, 2014 (66) • Babl et al, 2014 (60) • Babl & Bressan, 2015 (59) • Babl et al, 2017 (58) • Bozan et al, 2017 (63) • Babl et al, 2018 (61)
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C1**		A1 | A2 | A3 | B1 | B2 | B3 | ● | C2 | ●
Justification	The CATCH rule was developed in 2010 and tested successfully for internal validity (51). The rule was tested eight times for external validity and proved externally valid in all the reported studies (48, 58-60, 63, 66, 72, 81). The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to the CATCH rule is C1.		
References	Development and Internal Validation: • Osmond, M. H., & Stiell, I. G. (2002). Canadian assessment of tomography for childhood head injuries. University of Ottawa, Trauma Division of Pediatric Emergency Medicine Children's Hospital of Eastern Ontario. Personal communication. • Osmond, M. H., Klassen, T. P., Stiell, I. G., & Correll, R. (2006). The CATCH rule: a clinical decision rule for the use of computed tomography of the head in children with minor head injury. Academic Emergency Medicine, 13(5 Supplement 1), S11. • Osmond, M. H., Klassen, T. P., Wells, G. A., Correll, R., Jarvis, A., Joubert, G., ... & Nijssen-Jordan, C. (2010). CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. Canadian Medical Association Journal, 182(4), 341-348. External Validation: • Gerdung, C., Dowling, S., & Lang, E. (2012). Review of the CATCH study a clinical decision rule for the use of computed tomography in children with minor head injury. Canadian Journal of Emergency Medicine, 14(4), 247-251.		

	• Klement, W., Wilk, S., Michalowski, W., Farion, K. J., Osmond, M. H., & Verter, V. (2012). Predicting the need for CT imaging in children with minor head injury using an ensemble of Naive Bayes classifiers. Artificial intelligence in medicine, 54(3), 163-170. (We showed that the proposed ensemble model achieved a more balanced predictive performance than the CATCH rule with an average sensitivity of 82.8% and an average specificity of 74.4% (vs. 98.1% and 50.0% for the CATCH rule respectively). • Lyttle, M. D., Cheek, J. A., Blackburn, C., Oakley, E., Ward, B., Fry, A., ... & Babl, F. E. (2013). Applicability of the CATCH, CHALICE and PECARN paediatric head injury clinical decision rules: pilot data from a single Australian centre. Emerg Med J, 30(10), 790-794. • Easter, J. S., Bakes, K., Dhaliwal, J., Miller, M., Caruso, E., & Haukoos, J. S. (2014). Comparison of PECARN, CATCH, and CHALICE rules for children with minor head injury: a prospective cohort study. Annals of emergency medicine, 64(2), 145-152. • Babl, F. E., Lyttle, M. D., Bressan, S., Borland, M., Phillips, N., Kochar, A., ... & Gilhotra, Y. (2014). A prospective observational study to assess the diagnostic accuracy of clinical decision rules for children presenting to emergency departments after head injuries (protocol): the Australasian Paediatric Head Injury Rules Study (APHIRST). BMC pediatrics, 14(1), 148. • Babl, F. E., & Bressan, S. (2015). Physician practice and PECARN rule outperform CATCH and CHALICE rules based on the detection of traumatic brain injury as defined by PECARN. Evidence-based medicine, 20(1), 33-34. • Babl, F. E., Borland, M. L., Phillips, N., Kochar, A., Dalton, S., McCaskill, M., ... & Lyttle, M. D. (2017). Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. The Lancet. • Bozan, Ö., Aksel, G., Kahraman, H. A., Giritli, Ö., & Eroğlu, S. E. (2017). Comparison of PECARN and CATCH clinical decision rules in children with minor blunt head trauma. European Journal of Trauma and Emergency Surgery, 1-7. • Babl, F. E., Oakley, E., Dalziel, S. R., Borland, M. L., Phillips, N., Kochar, A., ... & Neutze, J. (2018). Accuracy of clinician practice compared with three head injury decision rules in children: a prospective cohort study. Annals of emergency medicine, 71(6), 703-710. Additional Commentary and Reviews: • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Lyttle, M. D., Crowe, L., Oakley, E., Dunning, J., & Babl, F. E. (2012). Comparing CATCH, CHALICE and PECARN clinical decision rules for paediatric head injuries. Emerg Med J, emermed-2011.
Colour Code	• Important Findings • Less Relevant Findings • Positive Findings • Negative Findings

7. NEXUS II Rule – Grade C1

Table 7: The GRASP Framework Detailed Report of the NEXUS II Rule

<table>
<tr><td>Name</td><td colspan="9">NEXUS II Rule for Adult/Paediatric Head Injury/Trauma</td></tr>
<tr><td>Authors/Year</td><td colspan="9">Dr. William R. Mower, United States, 2005 (designed the rule for adults) – Dr. Jennifer A Oman, United States, 2006 (validated the rule for paediatrics).</td></tr>
<tr><td>Category</td><td colspan="9">Diagnostic</td></tr>
<tr><td>Intended use</td><td colspan="9">Predict the need for computed tomography among children with head trauma</td></tr>
<tr><td>Intended user</td><td colspan="9">Physicians</td></tr>
<tr><td>Clinical area</td><td colspan="9">Emergency department (ED)</td></tr>
<tr><td>Target Population</td><td colspan="9">Children less than 18 years of age at ED for head trauma</td></tr>
<tr><td>Target Outcome</td><td colspan="9">Traumatic brain injury</td></tr>
<tr><td>Action</td><td colspan="9">Do/Do Not Consider CT + Acute intervention</td></tr>
<tr><td>Input source</td><td colspan="9">Objective data (clinical examination) + subjective data (reported by child/parents)</td></tr>
<tr><td>Input type</td><td colspan="9">Clinical data: Spontaneous eye opening, Orientation, Ability to follow commands, Seizure after trauma, Loss of consciousness, Prolonged loss of consciousness, Severe or progressive headache, Coagulopathy, Abnormal behaviour, Abnormal level of alertness, Evidence of significant skull fracture, Persistent vomiting, Evidence of intoxication, Motor deficit, Gait abnormality, Abnormal cerebellar function, Cranial nerve abnormality, Inability to read or write, Scalp hematoma, Neurologic deficit.</td></tr>
<tr><td>Local context</td><td colspan="9">Input does not depend on local context of data</td></tr>
<tr><td>Methodology</td><td colspan="9">Recursive partitioning</td></tr>
<tr><td>Int. Validation</td><td colspan="9">Cross validation</td></tr>
<tr><td>Dedicated Supp</td><td colspan="9">National Emergency X-Radiography Utilization Study II for the NEXUS II rule, USA.</td></tr>
<tr><td>Endorsement</td><td colspan="9">Not recommended by clinical guidelines</td></tr>
<tr><td>Automation Flag</td><td colspan="9">Manually used</td></tr>
<tr><td>Tool Citations</td><td>124</td><td colspan="8">Reported for paediatric head injury in 6 studies</td></tr>
<tr><td>Authors</td><td>8</td><td colspan="8">Sample Size = 1,666</td></tr>
<tr><td>Journal Impact</td><td>5.7</td><td colspan="8">Paediatrics</td></tr>
<tr><td>Phase of Evaluation</td><td>Level of Evidence</td><td>Grade</td><td colspan="7">Evaluation Studies</td></tr>
<tr><td rowspan="3">Phase C:
Before implementation
Does the tool work? Is it possible?</td><td>Internal validation</td><td>C3</td><td colspan="7">Developed and internally validated for adults:
• Mower et al, 2002 (88)
• Mower et al, 2005 (89)</td></tr>
<tr><td>External validation</td><td>C2</td><td colspan="7">Externally validated for paediatrics</td></tr>
<tr><td>External validation multiple times</td><td>C1</td><td colspan="7">Externally validated for paediatrics:
• Oman et al, 2006 (50)
• Sun, Hoffman & Mower, 2007 (54)
• Klemetti et al, 2009 (48)
• Stein et al, 2009 (86)
• Schachar et al, 2011 (85)
• Gupta et al, 2018 (84)</td></tr>
<tr><td rowspan="3">Phase B:
Planning for implementation:
Is the tool practicable?</td><td>Usability</td><td>B3</td><td colspan="7">Not reported</td></tr>
<tr><td>Potential effect</td><td>B2</td><td colspan="7">Not reported</td></tr>
<tr><td>Potential effect & Usability</td><td>B1</td><td colspan="7">Not reported</td></tr>
<tr><td rowspan="3">Phase A:
After implementation:
Is the tool desirable?</td><td rowspan="3">Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency</td><td>A3</td><td colspan="7">No subjective studies are reported</td></tr>
<tr><td>A2</td><td colspan="7">No observational studies are reported</td></tr>
<tr><td>A1</td><td colspan="7">No experimental studies are reported</td></tr>
<tr><td>Assigned Grade</td><td colspan="2">Grade C1</td><td>A1</td><td>A2</td><td>A3</td><td>B1</td><td>B2</td><td>B3</td><td>●</td><td>C2</td><td>●</td></tr>
</table>

Justification	The NEXUS II rule was developed in 2005 primarily for the diagnosis of adult head injury (88, 89). Later on, the rule was validated for paediatrics (50). The tool was then tested, four times, for external validity. One study failed to properly evaluate the rule after using a modified version, which did not show external validity (54). Two studies proved the rule was externally valid for children less than 14 and 16 years (48, 85) and one study proved the rule was externally valid for children over 10 years (86). Using the protocol, the mixed evidence here supports positive conclusion on external validity. The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to the NEXUS II rule is C1.
References	Development and Internal Validation for Adults: • Mower, W. R., Hoffman, J. R., Herbert, M., Wolfson, A. B., Pollack Jr, C. V., Zucker, M. I., & NEXUS II Investigators. (2002). Developing a clinical decision instrument to rule out intracranial injuries in patients with minor head trauma: methodology of the NEXUS II investigation. Annals of emergency medicine, 40(5), 505-515. • Mower, W. R., Hoffman, J. R., Herbert, M., Wolfson, A. B., Pollack Jr, C. V., Zucker, M. I., & NEXUS II Investigators. (2005). Developing a decision instrument to guide computed tomographic imaging of blunt head injury patients. Journal of Trauma and Acute Care Surgery, 59(4), 954-959. Externally Validated for Paediatrics – Positive Conclusions: • Oman, J. A., Cooper, R. J., Holmes, J. F., Viccellio, P., Nyce, A., Ross, S. E., ... & Mower, W. R. (2006). Predictive performance of a decision rule to predict need for computed tomography among children with blunt head trauma. Pediatrics, 117(2), e238-e246. An analysis was conducted of the pediatric cohort involved in the derivation set of National Emergency X-Radiography Utilization Study II (NEXUS II). We determined the test performance characteristics of the 8-variable NEXUS II decision instrument, derived from the entire NEXUS II cohort, in the pediatric cohort (0–18 years of age), as well as in the very young children (<3 years). The decision instrument derived in the large NEXUS II cohort performed with similarly high sensitivity among the subgroup of children who were included in this study. Clinically important ICI were rare in children who did not exhibit at least 1 of the NEXUS II risk criteria. • Sun, B. C., Hoffman, J. R., & Mower, W. R. (2007). Evaluation of a modified prediction instrument to identify significant pediatric intracranial injury after blunt head trauma. Annals of emergency medicine, 49(3), 325-332. In the NEXUS II cohort, a modified version of the University of California-Davis Rule misclassified a substantial proportion of paediatric patients with clinically important blunt head injury. Although we cannot evaluate the exact University of California-Davis Rule, we demonstrate that using stricter definitions of “headache” and “vomiting” and different wording than in the original study may have unintended or negative consequences. We emphasize the importance of careful attention to precise definitions of clinical predictors when a decision instrument is used. • Schachar, J. L., Zampolin, R. L., Miller, T. S., Farinhas, J. M., Freeman, K., & Taragin, B. H. (2011). External validation of the New Orleans Criteria (NOC), the Canadian CT Head Rule (CCHR) and the National Emergency X-Radiography Utilization Study II (NEXUS II) for CT scanning in pediatric patients with minor head injury in a non-trauma center. Pediatric radiology, 41(8), 971. • Gupta, M., Mower, W. R., Rodriguez, R. M., & Hendey, G. W. (2018). Validation of the Pediatric NEXUS II Head Computed Tomography Decision Instrument for Selective Imaging of Pediatric Patients with Blunt Head Trauma. Academic Emergency Medicine. Externally Validated for Paediatrics – Equivocal and Negative Conclusions: • Stein, S. C., Fabbri, A., Servadei, F., & Glick, H. A. (2009). A critical comparison of clinical decision instruments for computed tomographic scanning in mild closed traumatic brain injury in adolescents and adults. Annals of emergency medicine, 53(2), 180-188. NEXUS-II and the Scandinavian clinical decision aids displayed the best combination of sensitivity and specificity in this patient population (patients aged 10 years or older). • Klemetti, S., Uhari, M., Pokka, T., & Rantala, H. (2009). Evaluation of decision rules for identifying serious consequences of traumatic head injuries in pediatric patients. Pediatric emergency care, 25(12), 811-815. We found NEXUS II to be the best of the rules tested here. Systematic review studies:

	• Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154. • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718. • Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).	
Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings

8. Palchak Rule – Grade C2

Table 8: The GRASP Framework Detailed Report of Palchak Rule

Name	Palchak (UC Davis) Rule for Paediatric Head Injury/Trauma		
Authors/Year	Dr. Michael Palchak and Dr. Nathan Kuppermann, United States, 2003		
Category	Diagnostic		
Intended use	Identifies children at low risk for brain injuries after head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 18 years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Abnormal mental status, clinical signs of skull fracture, scalp hematoma in a child ≤2 y, history of vomiting and headache.		
Local context	Input does not depend on local context of data		
Methodology	Recursive partitioning		
Int. Validation	Cross validation		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	248	Reported in 3 studies	
Authors	10	Sample Size = 2,043	
Journal Impact	5.35	Annals of emergency medicine	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: **Before implementation**	Internal validation	**C3**	Developed and internally validated: • Palchak et al, 2003 (52) • Palchak, Holmes & Kuppermann, 2009 (87)

<table>
<tr><td rowspan="2">Does the tool work? Is it possible?</td><td>External validation</td><td>C2</td><td colspan="9">External validation:
• Klemetti et al, 2009 (48)</td></tr>
<tr><td>External validation multiple times</td><td>C1</td><td colspan="9">Not reported</td></tr>
<tr><td rowspan="3">Phase B:
Planning for implementation:
Is the tool practicable?</td><td>Usability</td><td>B3</td><td colspan="9">Not reported</td></tr>
<tr><td>Potential effect</td><td>B2</td><td colspan="9">Not reported</td></tr>
<tr><td>Potential effect & Usability</td><td>B1</td><td colspan="9">Not reported</td></tr>
<tr><td rowspan="3">Phase A:
After implementation:
Is the tool desirable?</td><td rowspan="3">Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency</td><td>A3</td><td colspan="9">No subjective studies are reported</td></tr>
<tr><td>A2</td><td colspan="9">No observational studies are reported</td></tr>
<tr><td>A1</td><td colspan="9">No experimental studies are reported</td></tr>
<tr><td>Assigned Grade</td><td colspan="2">Grade C2</td><td>A1</td><td>A2</td><td>A3</td><td>B1</td><td>B2</td><td>B3</td><td>C1</td><td>●</td><td>●</td></tr>
<tr><td>Justification</td><td colspan="11">Palchak rule was developed in 2003 and tested successfully for internal validity (52). A study by the same authors in 2009 included validation of the rule in comparison to clinician judgement using the same dataset that was used for the rule development; this is still considered an internal validation (87). One external validation study reported the predictive performance of Palchak rule was acceptable (48). The rule was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Palchak rule is C2.</td></tr>
<tr><td>References</td><td colspan="11">Development and Internal Validation:
• Palchak, M. J., Holmes, J. F., Vance, C. W., Gelber, R. E., Schauer, B. A., Harrison, M. J., ... & Kuppermann, N. (2003). A decision rule for identifying children at low risk for brain injuries after blunt head trauma. Annals of emergency medicine, 42(4), 492-506.
• Palchak, M. J., Holmes, J. F., & Kuppermann, N. (2009). Clinician judgment versus a decision rule for identifying children at risk of traumatic brain injury on computed tomography after blunt head trauma. Pediatric emergency care, 25(2), 61-65.
External validation:
• Klemetti, S., Uhari, M., Pokka, T., & Rantala, H. (2009). Evaluation of decision rules for identifying serious consequences of traumatic head injuries in pediatric patients. Pediatric emergency care, 25(12), 811-815.
Additional Commentary and Reviews:
• Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154.
• Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677.
• Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421.
• Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.
• Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).</td></tr>
<tr><td>Colour Code</td><td colspan="5">• Important Findings
• Less Relevant Findings</td><td colspan="6">• Positive Findings
• Negative Findings</td></tr>
</table>

9. Haydel Rule – Grade C3

Table 9: The GRASP Framework Detailed Report of Haydel Rule

Name	Haydel Rule for Paediatrics Head Injury/Trauma		
Authors/Year	Dr. Micelle J. Haydel, United States, 2003		
Category	Diagnostic		
Intended use	Identifies children at low risk for traumatic brain injuries after head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children aged 5 to 17 years at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: scalp hematoma, scalp abrasion, scalp laceration, forehead contusion, headache, vomiting, short-term memory deficit.		
Local context	Input does not depend on local context of data		
Methodology	Recursive partitioning		
Int. Validation	Separate validation population		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	118	Reported in 1 study	
Authors	5	Sample Size = 175	
Journal Impact	5.35	Annals of emergency medicine	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: **Before implementation** **Does the tool work? Is it possible?**	Internal validation	**C3**	Developed and internally validated: • Haydel & Shembekar, 2003 (47)
	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B: **Planning for implementation:** **Is the tool practicable?**	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: **After implementation:** **Is the tool desirable?**	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C3**		A1 / A2 / A3 / B1 / B2 / B3 / C1 / C2 / ●
Justification	Haydel rule was developed and tested successfully for internal validity in 2003 (47). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Greenes rule is C3.		
References	Development and Internal Validation: • Haydel, M. J., & Shembekar, A. D. (2003). Prediction of intracranial injury in children aged five years and older with loss of consciousness after minor head injury due to nontrivial mechanisms. Annals of emergency medicine, 42(4), 507-514. Additional Commentary and Reviews:		

	• Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154. • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718.	
Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings

10. Atabaki Rule – Grade C3

Table 10: The GRASP Framework Detailed Report of Atabaki Rule

Name	Atabaki Rule for Paediatric Head Injury/Trauma		
Authors/Year	Dr. Shireen M. Atabaki, United States, 2008		
Category	Diagnostic		
Intended use	Identifies children at low risk for brain injuries after mild head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 21 years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Mechanism of injury, loss of consciousness, amnesia, mental status change, lethargy, seizure, headache, vomiting, dizziness, drug or alcohol, sensory deficit, skull defect, basal skull fracture, scalp hematoma/laceration, and Glasgow coma scale score		
Local context	Input does not depend on local context of data		
Methodology	Recursive partitioning		
Int. Validation	Cross validation		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	111	Reported in 1 study	
Authors	8	Sample Size = 1,000	
Journal Impact	5.73	Archives of paediatrics & adolescent medicine	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation	Internal validation	**C3**	Developed and internally validated: • Atabaki et al, 2008 (39)
	External validation	**C2**	Not reported

Does the tool work? Is it possible?	External validation multiple times	**C1**	Not reported
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C3**		A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | ●
Justification	Atabaki rule was developed and tested successfully for internal validity in 2008 (39). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Atabaki rule is C3.		
References	Development and Internal Validation: • Atabaki, S. M., Stiell, I. G., Bazarian, J. J., Sadow, K. E., Vu, T. T., Camarca, M. A., ... & Chamberlain, J. M. (2008). A clinical decision rule for cranial computed tomography in minor pediatric head trauma. Archives of pediatrics & adolescent medicine, 162(5), 439-445. Systematic review studies: • Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154. • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718. • Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).		
Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings	

11. Buchanich Rule – Grade C3

Table 11: The GRASP Framework Detailed Report of Buchanich Rule

Name	Buchanich Rule for Paediatric Head Injury/Trauma		
Authors/Year	Dr. Jeanine M. Buchanich, United States, 2007		
Category	Diagnostic		
Intended use	Identifies children at low risk for brain injuries after mild head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than three years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: vision changes, scalp lacerations, history of vomiting, abnormal mental status, clinical signs of skull fracture, and headache.		
Local context	Input does not depend on local context of data		
Methodology	Recursive partitioning		
Int. Validation	Cross validation		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	4	Reported in 1 study	
Authors	1	Sample Size = 97	
Journal Impact	1	Doctoral dissertation, University of Pittsburgh	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed and internally validated: • Buchanich, 2007 (40)
	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C3**		A1 A2 A3 B1 B2 B3 C1 C2 ●
Justification	Buchanich rule was developed and tested successfully for internal validity in 2007 (40). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Buchanich rule is C3.		
References	Development and Internal Validation: • Buchanich, J. M. (2007). A clinical decision-making rule for mild head injury in children less than three years old (Doctoral dissertation, University of Pittsburgh). Systematic review studies:		

	• Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Tavarez, M. M., Atabaki, S. M., & Teach, S. J. (2012). Acute evaluation of pediatric patients with minor traumatic brain injury. Current opinion in pediatrics, 24(3), 307-313. • Pandor, A., Harnan, S., Goodacre, S., Pickering, A., Fitzgerald, P., & Rees, A. (2012). Diagnostic accuracy of clinical characteristics for identifying CT abnormality after minor brain injury: a systematic review and meta-analysis. Journal of neurotrauma, 29(5), 707-718. • Shiomi, N., Echigo, T., Hino, A., Hashimoto, N., & Yamaki, T. (2016). Criteria for CT and initial management of head injured infants: A review. Neurologia medico-chirurgica, 56(7), 442-448.
Colour Code	• Important Findings • Less Relevant Findings • Positive Findings • Negative Findings

12. Da Dalt Rule – Grade C0

Table 12: The GRASP Framework Detailed Report of Da Dalt Rule

Name	Da Dalt Rule for Paediatric Head Injury/Trauma		
Authors/Year	Dr. Liviana Da Dalt, Italy, 2006		
Category	Diagnostic		
Intended use	Predict the need for computed tomography among children with head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 16 years at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Loss of consciousness, prolonged headache, vomiting, Impact seizure, drowsiness, amnesia, abnormal neurological examination, lower Glasgow Coma Scale, and clinical evidence of basal or non-frontal skull fracture.		
Local context	Input does not depend on local context of data		
Methodology	Multivariate logistic regression analysis		
Int. Validation	Not reported		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	85	Reported in 1 study	
Authors	8	Sample Size = 3,806	
Journal Impact	1.79	European journal of paediatrics	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed but not tested for internal validity: • Da Dalt et al, 2006 (41)
	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B:	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported

Planning for implementation: Is the tool practicable?	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported

Assigned Grade	**Grade C0**	A1	A2	A3	B1	B2	B3	C1	C2	O

Justification	Da Dalt rule was developed in 2006 but was not tested for internal validity (41). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Da Dalt rule is C0.
References	Development and Internal Validation: • Da Dalt, L., Marchi, A. G., Laudizi, L., Crichiutti, G., Messi, G., Pavanello, L., ... & Barbone, F. (2006). Predictors of intracranial injuries in children after blunt head trauma. European journal of pediatrics, 165(3), 142-148. (Not tested for internal validity). Additional Commentary and Reviews: • Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154. • Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677. • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.

Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings

13. Greenes Rule – Grade C0

Table 13: The GRASP Framework Detailed Report of Greenes Rule

Name	Greenes Rule for Paediatrics Head Injury/Trauma
Authors/Year	Dr. David S. Greenes, United States, 2001
Category	Diagnostic
Intended use	Identifies infants at low risk for brain injuries after head trauma
Intended user	Physicians
Clinical area	Emergency department (ED)
Target Population	Infants less than two years of age at ED for head trauma
Target Outcome	Traumatic brain injury
Action	Do/Do Not Consider CT + Acute intervention
Input source	Objective data (clinical examination) + subjective data (reported by parents)
Input type	Clinical data: Age in months, scalp haematoma size, haematoma location.
Local context	Input does not depend on local context of data
Methodology	Multivariate logistic regression analysis

Int. Validation	Not reported		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	237	Reported in 2 studies	
Authors	2	Sample Size = 422	
Journal Impact	5.7	Paediatrics	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed but not tested for internal validity: • Greenes & Schutzman, 1999 (44) • Greenes & Schutzman, 2001 (45)
	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C0**		A1 A2 A3 B1 B2 B3 C1 C2 O
Justification	Greenes rule was developed in 2001 but was not tested for internal validity (44, 45). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Greenes rule is C0.		

References

Development and Internal Validation:

- Greenes, D. S., & Schutzman, S. A. (1999). Clinical indicators of intracranial injury in head-injured infants. Pediatrics, 104(4), 861-867. (Not tested for internal validity).
- Greenes, D. S., & Schutzman, S. A. (2001). Clinical significance of scalp abnormalities in asymptomatic head-injured infants. Pediatric emergency care, 17(2), 88-92. (Not tested for internal validity).

Systematic review studies:

- Maguire, J. L., Boutis, K., Uleryk, E. M., Laupacis, A., & Parkin, P. C. (2009). Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics, 124(1), e145-e154.
- Maguire, J. L., Kulik, D. M., Laupacis, A., Kuppermann, N., Uleryk, E. M., & Parkin, P. C. (2011). Clinical prediction rules for children: a systematic review. Pediatrics, 128(3), e666-e677.
- Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421.
- Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.
- Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).

	• Bressan, S., Marchetto, L., Lyons, T. W., Monuteaux, M. C., Freedman, S. B., Da Dalt, L., & Nigrovic, L. E. (2017). A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Annals of emergency medicine.	
Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings

14. Klemetti Rule – Grade C0

Table 14: The GRASP Framework Detailed Report of Klemetti Rule

Name	Klemetti Rule for Paediatrics Head Injury/Trauma		
Authors/Year	Dr. Sanna Klemetti, Finland, 2009		
Category	Diagnostic		
Intended use	Identifies children at low risk for traumatic brain injuries after head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 16 years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Abnormal mental status, signs of skull fracture, neurologic deficit, scalp trauma, loss of consciousness, and vertigo.		
Local context	Input does not depend on local context of data		
Methodology	Multivariate logistic regression analysis		
Int. Validation	Not reported		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	18	Reported in 1 study	
Authors	4	Sample Size = 485	
Journal Impact	1.07	Paediatric emergency care	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation Does the tool work? Is it possible?	Internal validation	**C3**	Developed but not tested for internal validity: • Klemetti et al, 2009 (48)
	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C0**		A1 A2 A3 B1 B2 B3 C1 C2 O

Justification	Klemetti rule was developed in 2009 but was not tested for internal validity (48). The rule was not tested for external validity. It was not evaluated for usability, potential effect or post-implementation impact. Accordingly, the final grade assigned to Klemetti rule is C0.
References	Development and Internal Validation: • Klemetti, S., Uhari, M., Pokka, T., & Rantala, H. (2009). Evaluation of decision rules for identifying serious consequences of traumatic head injuries in pediatric patients. Pediatric emergency care, 25(12), 811-815. (Not tested for internal validity). Additional Commentary and Reviews: • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1. • Sempértegui Cárdenas, P. X. (2016). Validación de una escala de predicción de lesiones intracraneales para trauma cráneo-encefálico en niños de 0 a 5 años del Hospital Vicente Corral Moscoso Enero-Diciembre 2014. Estudio de test diagnóstico (Master's thesis).
Colour Code	• Important Findings • Less Relevant Findings • Positive Findings • Negative Findings

15. Quayle Rule – Grade C0

Table 15: The GRASP Framework Detailed Report of Quayle Rule

Name	Quayle Rule for Paediatrics Head Injury/Trauma		
Authors/Year	Dr. Kimberly S. Quayle, Unites States, 1997		
Category	Diagnostic		
Intended use	Identifies children at low risk for brain injuries after head trauma		
Intended user	Physicians		
Clinical area	Emergency department (ED)		
Target Population	Children less than 18 years of age at ED for head trauma		
Target Outcome	Traumatic brain injury		
Action	Do/Do Not Consider CT + Acute intervention		
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)		
Input type	Clinical data: Altered mental status, focal neurologic deficit, seizure, signs of a basilar skull fracture, loss of consciousness for more than 5 minutes, and skull fracture.		
Local context	Input does not depend on local context of data		
Methodology	Multivariate logistic regression analysis		
Int. Validation	Not reported		
Dedicated Supp	Not supported by any research networks, programs, or professional groups.		
Endorsement	Not recommended by clinical guidelines		
Automation Flag	Manually used		
Tool Citations	291	Reported in 1 study	
Authors	7	Sample Size = 322	
Journal Impact	5.7	Paediatrics	
Phase of Evaluation	**Level of Evidence**	**Grade**	**Evaluation Studies**
Phase C: Before implementation	Internal validation	**C3**	Developed but not tested for internal validity: • Quayle et al, 1997 (53)

Does the tool work? Is it possible?	External validation	**C2**	Not reported
	External validation multiple times	**C1**	Not reported
Phase B: Planning for implementation: Is the tool practicable?	Usability	**B3**	Not reported
	Potential effect	**B2**	Not reported
	Potential effect & Usability	**B1**	Not reported
Phase A: After implementation: Is the tool desirable?	Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency	**A3**	No subjective studies are reported
		A2	No observational studies are reported
		A1	No experimental studies are reported
Assigned Grade	**Grade C0**		A1 A2 A3 B1 B2 B3 C1 C2 O
Justification	Dr. Kimberly Quayle in 1997 tried to develop a clinical prediction rule, to identify children at low risk for traumatic brain injuries after head trauma, through determining clinical signs and symptoms that can reliably predict an abnormality on cranial computed tomography (CT) (53). The study could not produce a predictive rule with sufficient internal validity. Accordingly, the final grade assigned to this rule is C0.		
References	Development and Internal Validation: • Quayle, K. S., Jaffe, D. M., Kuppermann, N., Kaufman, B. A., Lee, B. C., Park, T. S., & McAlister, W. H. (1997). Diagnostic testing for acute head injury in children: when are head computed tomography and skull radiographs indicated?. Pediatrics, 99(5), e11-e11. (Not tested for internal validity). Additional Commentary and Reviews: • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.		
Colour Code	• Important Findings • Less Relevant Findings		• Positive Findings • Negative Findings

16. Dietrich Rule – Grade C0

Table 16: The GRASP Framework Detailed Report of Dietrich Rule

Name	Dietrich Rule for Paediatrics Head Injury/Trauma
Authors/Year	Dr. Ann Dietrich, United States, 1993
Category	Diagnostic
Intended use	Identifies children at low risk for brain injuries after head trauma
Intended user	Physicians
Clinical area	Emergency department (ED)
Target Population	Children less than 21 years of age at ED for head trauma
Target Outcome	Traumatic brain injury
Action	Do/Do Not Consider CT + Acute intervention
Input source	Objective data (clinical examination) + subjective data (reported by child/parents)
Input type	Clinical data: e.g. Loss of consciousness, clinical signs of focal neuro-deficits, seizures, and history of vomiting and headache.
Local context	Input does not depend on local context of data

<table>
<tr><td>Methodology</td><td colspan="10">Multivariate logistic regression analysis</td></tr>
<tr><td>Int. Validation</td><td colspan="10">Not reported</td></tr>
<tr><td>Dedicated Supp</td><td colspan="10">Not supported by any research networks, programs, or professional groups.</td></tr>
<tr><td>Endorsement</td><td colspan="10">Not recommended by clinical guidelines</td></tr>
<tr><td>Automation Flag</td><td colspan="10">Manually used</td></tr>
<tr><td>Tool Citations</td><td>220</td><td colspan="9">Reported in 1 study</td></tr>
<tr><td>Authors</td><td>5</td><td colspan="9">Sample Size = 324</td></tr>
<tr><td>Journal Impact</td><td>5.35</td><td colspan="9">Annals of emergency medicine</td></tr>
<tr><td>Phase of Evaluation</td><td>Level of Evidence</td><td>Grade</td><td colspan="8">Evaluation Studies</td></tr>
<tr><td rowspan="3">Phase C:
Before implementation
Does the tool work? Is it possible?</td><td>Internal validation</td><td>C3</td><td colspan="8">Developed but not tested for internal validity:
• Dietrich et al, 1993 (42)</td></tr>
<tr><td>External validation</td><td>C2</td><td colspan="8">Not reported</td></tr>
<tr><td>External validation multiple times</td><td>C1</td><td colspan="8">Not reported</td></tr>
<tr><td rowspan="3">Phase B:
Planning for implementation:
Is the tool practicable?</td><td>Usability</td><td>B3</td><td colspan="8">Not reported</td></tr>
<tr><td>Potential effect</td><td>B2</td><td colspan="8">Not reported</td></tr>
<tr><td>Potential effect & Usability</td><td>B1</td><td colspan="8">Not reported</td></tr>
<tr><td rowspan="3">Phase A:
After implementation:
Is the tool desirable?</td><td rowspan="3">Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency</td><td>A3</td><td colspan="8">No subjective studies are reported</td></tr>
<tr><td>A2</td><td colspan="8">No observational studies are reported</td></tr>
<tr><td>A1</td><td colspan="8">No experimental studies are reported</td></tr>
<tr><td>Assigned Grade</td><td colspan="2">Grade C0</td><td>A1</td><td>A2</td><td>A3</td><td>B1</td><td>B2</td><td>B3</td><td>C1</td><td>C2</td></tr>
<tr><td>Justification</td><td colspan="10">Dr. Ann Dietrich in 1993 tried to develop a clinical prediction rule, to identify children at low risk for traumatic brain injuries after head trauma, through determining clinical factors that reliably predict an abnormality on computed tomography (CT) (42). Dr. Dietrich study could not demonstrate a good correlation between the clinical symptoms of significant traumatic brain injury and the findings on the CT. The proposed rule did not have sufficient internal validity to be tested for external validity or to be implemented. Accordingly, the final grade assigned to this rule is C0.</td></tr>
<tr><td>References</td><td colspan="10">Development and Internal Validation:
• Dietrich, A. M., Bowman, M. J., Ginn-Pease, M. E., Kosnik, E., & King, D. R. (1993). Pediatric head injuries: can clinical factors reliably predict an abnormality on computed tomography?. Annals of emergency medicine, 22(10), 1535-1540. (Not tested for internal validity).

Additional Commentary and Reviews:
• Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421.
• Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.</td></tr>
<tr><td>Colour Code</td><td colspan="5">• Important Findings
• Less Relevant Findings</td><td colspan="5">• Positive Findings
• Negative Findings</td></tr>
</table>

17. Güzel Rule – Grade C0

Table 17: The GRASP Framework Detailed Report of Güzel Rule

<table>
<tr><td>Name</td><td colspan="3">Güzel Rule for Paediatrics Head Injury/Trauma</td></tr>
<tr><td>Authors/Year</td><td colspan="3">Dr. Ahmet Güzel, Turkey, 2009</td></tr>
<tr><td>Category</td><td colspan="3">Diagnostic</td></tr>
<tr><td>Intended use</td><td colspan="3">Identifies children at low risk for traumatic brain injuries after head trauma</td></tr>
<tr><td>Intended user</td><td colspan="3">Physicians</td></tr>
<tr><td>Clinical area</td><td colspan="3">Emergency department (ED)</td></tr>
<tr><td>Target Population</td><td colspan="3">Children less than 15 years of age at ED for head trauma</td></tr>
<tr><td>Target Outcome</td><td colspan="3">Traumatic brain injury</td></tr>
<tr><td>Action</td><td colspan="3">Do/Do Not Consider CT + Acute intervention</td></tr>
<tr><td>Input source</td><td colspan="3">Objective data (clinical examination) + subjective data (reported by child/parents)</td></tr>
<tr><td>Input type</td><td colspan="3">Clinical data: cause of injury, headache, post-traumatic amnesia, loss of consciousness, blurred vision, seizures, head lacerations, scalp haematoma, periorbital ecchymosis, otorrhea, skull fractures, and abnormal neurological findings.</td></tr>
<tr><td>Local context</td><td colspan="3">Input does not depend on local context of data</td></tr>
<tr><td>Methodology</td><td colspan="3">Multivariate logistic regression analysis</td></tr>
<tr><td>Int. Validation</td><td colspan="3">Not reported</td></tr>
<tr><td>Dedicated Supp</td><td colspan="3">Not supported by any research networks, programs, or professional groups.</td></tr>
<tr><td>Endorsement</td><td colspan="3">Not recommended by clinical guidelines</td></tr>
<tr><td>Automation Flag</td><td colspan="3">Manually used</td></tr>
<tr><td>Tool Citations</td><td>17</td><td colspan="2">Reported in 1 study</td></tr>
<tr><td>Authors</td><td>6</td><td colspan="2">Sample Size = 916</td></tr>
<tr><td>Journal Impact</td><td>1</td><td colspan="2">Paediatric neurosurgery</td></tr>
<tr><td>Phase of Evaluation</td><td>Level of Evidence</td><td>Grade</td><td>Evaluation Studies</td></tr>
<tr><td rowspan="3">Phase C:
Before implementation
Does the tool work? Is it possible?</td><td>Internal validation</td><td>C3</td><td>Developed but not tested for internal validity:
• Güzel et al, 2009 (46)</td></tr>
<tr><td>External validation</td><td>C2</td><td>Not reported</td></tr>
<tr><td>External validation multiple times</td><td>C1</td><td>Not reported</td></tr>
<tr><td rowspan="3">Phase B:
Planning for implementation:
Is the tool practicable?</td><td>Usability</td><td>B3</td><td>Not reported</td></tr>
<tr><td>Potential effect</td><td>B2</td><td>Not reported</td></tr>
<tr><td>Potential effect & Usability</td><td>B1</td><td>Not reported</td></tr>
<tr><td rowspan="3">Phase A:
After implementation:
Is the tool desirable?</td><td rowspan="3">Evaluation of post-implementation impact on Clinical Effectiveness, Patient Safety or Healthcare Efficiency</td><td>A3</td><td>No subjective studies are reported</td></tr>
<tr><td>A2</td><td>No observational studies are reported</td></tr>
<tr><td>A1</td><td>No experimental studies are reported</td></tr>
<tr><td>Assigned Grade</td><td colspan="2">Grade C0</td><td>A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | O</td></tr>
<tr><td>Justification</td><td colspan="3">Dr. Ahmet Güzel in 2009 tried to develop a clinical prediction rule, to identify children at low risk for traumatic brain injuries after head trauma, through determining clinical risk factors that can be used as predictors of abnormalities in cranial computed tomography scans following minor head injury. The study could not produce a predictive rule with sufficient internal validity (46). Accordingly, the final grade assigned to this rule is C0.</td></tr>
<tr><td>References</td><td colspan="3">Development and Internal Validation:
• Güzel, A., Hiçdönmez, T., Temizöz, O., Aksu, B., Aylanç, H., & Karasalihoglu, S. (2009). Indications for brain computed tomography and hospital admission in</td></tr>
</table>

	pediatric patients with minor head injury: how much can we rely upon clinical findings?. Pediatric neurosurgery, 45(4), 262-270. (Not tested for internal validity). Additional Commentary and Reviews: • Pickering, A., Harnan, S., Fitzgerald, P., Pandor, A., & Goodacre, S. (2011). Clinical decision rules for children with minor head injury: a systematic review. Archives of disease in childhood, 96(5), 414-421. • Pandor, A., Goodacre, S., Harnan, S., Holmes, M., Pickering, A., Fitzgerald, P., ... & Stevenson, M. (2011). Diagnostic management strategies for adults and children with minor head injury: a systematic review and an economic evaluation. Health technology assessment (Winchester, England), 15(27), 1.	
Colour Code	• Important Findings • Less Relevant Findings	• Positive Findings • Negative Findings