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To what extent are GCS and AVPU equivalent to each other when assessing the level of consciousness of children with head injury? A cross-sectional study of UK hospital admissions.

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ABSTRACT

Objective To evaluate utility and equivalence of Glasgow Coma Scale (GCS) and the Alert, Voice, Pain, Unresponsive (AVPU) scale in children with head injury.

Design Cross sectional study.

Setting UK hospital admissions: September 2009–February 2010.

Patients <15 years with head injury.

Interventions GCS and/or AVPU at injury scene and in emergency departments (ED).

Main outcome Measures used, the equivalence of AVPU to GCS, GCS at the scene predicting GCS in ED, CT results by age, hospital type.

Results Level of consciousness was recorded in 91% (5168/5700) in ED (43%: GCS/30.5%: GCS+AVPU/17.3%: AVPU) and 66.1% (1190/1801) prehospital (33%: GCS/26%GCS+AVPU/7%: AVPU). Failure to record level of consciousness and the use of AVPU were greatest for infants. Correlation between AVPU and median GCS in 1147 children <5 years: A=15, V=14, P=8, U=3, for 1163 children ≥5 years: A=15, V=13, P=11, U=3. There was no significant difference in the proportion of infants who had a CT whether AVPU=V/P/U or GCS<15. However diagnostic yield of intracranial injury or depressed fracture was significantly greater for V/P/U than GCS<15 :7/7: 100% (95% CI 64.6% to 100%) versus 5/17: 29.4% (95% CI 13.3% to 53.1%). For children >1 year significantly more had a CT scan when GCS<14 was recorded than 'V/P/U only' and the diagnostic yield was greater. Prehospital GCS and GCS in the ED were the same for 77.4% (705/911).

Conclusion There was a clear correlation between Alert and GCS=15 and between Unresponsive and GCS=3 but a wider range of GCS scores for responsive to Pain or Voice that varied with age. AVPU was valuable at initial assessment of infants and did not adversely affect the proportion of infants who had head CT or the diagnostic yield.

Strengths and limitations of this study

- This is the largest study to explore the equivalence of AVPU to Glasgow Coma Scale (GCS) in children admitted to hospital with head injury.
- It is the only study to date to compare the outcomes for AVPU and GCS in children with head injury.
- The retrospective, multicentre design may limit findings due to impaired completeness and variation in data quality.
- Study numbers are limited by the lower numbers of children with severe loss of consciousness, however this represents real world epidemiology.

INTRODUCTION

An estimated 30 000 children are admitted to hospitals in England annually with head injury.[1] Although the majority of injuries are mild with a low mortality rate (<0.5%), an estimated 15%–20% have moderate to severe traumatic brain injury.[2] Children with impaired levels of consciousness have the greatest risk of significant morbidity or mortality.[2 3] Clinicians rely on scores, such as the Glasgow Coma Scale (GCS) to evaluate levels of consciousness to identify children who need further investigation and early intervention.[4]

Teasdale and Jennet devised the GCS in 1974 (modified in 1976)[4 5] (online supplementary table 1). It scores levels of neurological dysfunction in three components; motor, verbal and eye opening responses that are considered separately and combined into an overall score. Evaluating levels of consciousness in young children is challenging due to their limited verbal and motor responses, and several adaptations to the GCS for <5 years olds have been proposed.[6] UK head injury guidelines recommend the paediatric GCS (pGCS) for infants <1 year old.[3 7]

National Institute for Health and Care Excellence (NICE) guidelines from 2003 to 2014 recommend that all children with a head injury have a GCS recorded at prehospital assessment and when seen in emergency

departments (ED), that infants have a CT scan when GCS is <15 and for the older children CT is recommended when GCS<14[3] Ambulance staff, ED and child health clinicians receive regular updated training in its application. The score provides a baseline to facilitate triage, monitor levels of consciousness and aid decisions about whether CT imaging is required, the level of care and need for specialist involvement. However, studies have identified high levels of inter-rater variability, and variability in outcome prediction based on GCS.[8 9]

The complexity of the GCS compared with other simpler scores raises concerns about its utility[10] and alternative shorter scores are used. The AVPU score (online supplementary table 1) was introduced by the American College of Surgeons[11] to monitor the patients with poisoning.[12] It is less detailed and has four broad scores, A, *A*lert; V, responsive to *V*erbal stimulus; P, responsive to *P*ainful stimulus; U, *U*nresponsive. No formal training is required to administer this score and it can be used easily at the site of injury.[13]

The Confidential Enquiry into Head Injury in Childhood was the principal project within the Centre for Maternal and Child Enquires (CMACE) collected data from hospital admissions for head injury across the UK. This large dataset provided the opportunity to evaluate the clinical practice of recording levels of consciousness for children with head injury.

This study aims to describe the utilisation of GCS and AVPU in children with head injury, to determine the correlation between AVPU and GCS scores for children older and those younger than 5 years of age and to explore whether the scoring system that is used to measure of level of consciousness affects the rate of CT scan and subsequent diagnostic yield.

METHODS

Data were collected from the case notes of children up to 15 years of age admitted to hospital for more than 4 hours following a head injury between September 2009 and February 2010. Ninety per cent of hospitals that admit children for head injury in England, Wales, Northern Ireland and the Channel islands participated in the study.[14] Children with superficial or facial injuries that were unlikely to be associated with brain injury were excluded. The data collection proformas were designed to follow the child's pathway of care and to obtain information that was available from the child's hospital records. Proformas (online supplementary figure 1a,b) were completed by local head injury enquiry coordinators (previously identified in each hospital) and entered onto a secure CMACE database and placed in SPSS Statistics V.19 for analysis.

Data were collected for each child for GCS total and component scores, AVPU score, age, the type of hospital to which the child was admitted (specialist hospitals were defined as designated children's hospital, or those that became major trauma centres in 2012 and general hospitals, were those that had none of these facilities), whether or not the children received a CT scan and the diagnostic yield of intracranial abnormality or depressed fracture.

Analysis

We describe the proportion of children <15 years who had their level of consciousness recorded using GCS or AVPU respectively in the prehospital setting and at the first clinical assessment at ED. We have calculated the median and IQR of GCS scores for each aspect of AVPU to determine the correlation between GCS and AVPU for children <5 years old and those >5 where both scores were applied.

We compared the proportion of CT scans undertaken and the CT findings, between children who had their level of consciousness measured using AVPU, those measured with GCS and those where both scores were recorded to determine whether there was any difference according to the method used to record level of consciousness. This was undertaken for children <1 year and those >1 year as NICE guidelines lines for when a head CT scan should be undertaken vary for these two age groups[3]: for infants, a CT scan is recommended in those where GCS<15, where AVPU only was recorded we extrapolated that this should be equivalent of a V/P/U. For older children the recommendation is for a CT scan if GCS<14, again we chose a cut-off of V/P/U when GCS was not recorded.

We described the association between prehospital GCS and GCS in the ED to determine the extent of change between ambulance recorded GCS and that on admission. All analyses were undertaken using the online tool Vassar Stats[15] to calculate 95% CIs of proportion based on continuity-corrected versions of the Wilson interval. Fisher's exact test was used to calculate levels of significance at $p<0.05$.

Patient and public involvement

This was an analysis undertaken from data collected for the National Child Health Outcome review on head injuries, based on a National Health Service priority. Both patients and professionals were consulted during design of the study proformas. Patient recruitment was via anonymised case note review, with ethical and CAG approvals. The overall study findings have been disseminated in a publicly available report.

RESULTS

Overall, 5700 children were included in the study, median age 49 months, 61.4% (3500) were boys (online supplementary figure 2), 1801 children were transported to hospital by ambulance and 385 were transferred on to a second hospital (data were available for 318 of these latter cases).

Overall 90.6% (5168/5700) of children had their consciousness level recorded in the ED at the first hospital to which they were admitted, as did 85% (271/318) of children who were transferred to a second hospital, 66.1% (1190/1801) of the children transported to hospital by

Table 1 The proportion of children (n=5700) who had GCS or AVPU recorded in prehospital setting and on admission to subsequent hospitals.

	GCS only % (95% CI) (n)	GCS and AVPU % (n)	AVPU only % (n)	Not recorded % (n)	Total
Prehospital assessment	33.0% (594)	25.9% (467)	7.2% (129)	33.9% (611)	1801
Hospital assessment in ED	42.9% (2443)	30.5% (1739)	17.3% (986)	9.3% (532)	5700
Second hospital assessment on admission	47.2% (150)	29.6% (94)	8.5% (27)	14.8% (47)	318
Total	3187 (40.7%)	2300 (29.4%)	1142 (14.6%)	1190 (15.2%)	7819

ED, emergency departments; GCS, Glasgow Coma Scale.

ambulance had their consciousness level recorded at the scene of the incident (table 1).

The proportion of children who had an 'AVPU only' or no recording was higher for younger children and decreased with age, whereas the proportion of children who had a 'GCS only' increased with the age (figure 1). Overall 73.5% (4426/6018) of child hospital attendances had a GCS recorded. Of the total 5487 GCS recorded only 75.4% (4137) had the component scores documented.

Children were first taken to a general hospital in 83.6% (4768) of cases, and specialist hospitals in the remainder. The specialist hospitals recorded an APVU in significantly fewer cases than the general hospitals (13.6%: 95% CI 11.6% to 16.0% vs 18%: 95% CI 16.9% to 19.1%) (figure 1).

Correlation between AVPU and GCS

In the complete dataset 2300 children had both AVPU and GCS recorded at the same point of care. Of these AVPU scores, 91.4% (2102)=A, 4% (92)=V, 2% (47)=P and 2.6% (59)=U. The correlation between AVPU and GCS differed between the 1137 children <5 years and those ≥5 years old (n=1163). For children <5 years, the median scores and IQRs were A=15 (IQR 0), V=14 (IQR 13–15), P=8 (IQR 6–9) and U=3 (IQR 3–6) (online supplementary figure 3a). There was no significant difference within this age band between those younger and those >1 year of age. For children of ≥5 years, the median scores were A=15 (IQR 0), V=13 (IQR 12–14), P=11 (8 to 12) and U=3 (IQR 3–5) (online supplementary figure 3b).

For children <1 year and those >1 year, was there any difference between the proportion of CT scans performed and the diagnostic yield according to the method of recording the level of consciousness?

Table 2 shows that there was no statistically significant difference between the proportion of CT scans undertaken in the three groups of infants, (i) with a GCS<15, (ii) where the AVPU score was V/P/U or (iii) those with a recorded AVPU=V/P/U and a GCS<15. While numbers were small, significantly more infants with AVPU=V/P/U or V/P/U and GCS<15 had intracranial injury (ICI) or depressed fracture on CT than those who had a GCS<15 (p<0.01). When infants were Alert and/or GCS was 15, 10.2%–23.8% of children who had a CT scan had an abnormality identified.

For the older children, a significantly greater proportion of children had a CT when the GCS was <14, or the AVPU was V/P/U and GCS<14 than when the AVPU only was recorded as V/P/U (p<0.001). The diagnostic yield was significantly greater in these two groups than when AVPU only was recorded (table 2). For children who were Alert and/or who had a GCS=14/15, 7.6%–12.4% who had a CT scan had an abnormality.

When both AVPU and GCS were recorded and there was an apparent discrepancy between the scores (ie, Alert with a GCS<15 or GCS of 15 and AVPU=V/P/U), it was not possible to determine what influenced the decision to undertake a CT scan.

To what extent does GCS recorded at the scene of injury reflect the GCS on admission?

The GCS at the scene had a positive predictive value (PPV) of 77.4% (705/911) for the same GCS in the ED. The PPV for a GCS of 15 on hospital admission for children with a prehospital GCS of 15 was 88.6%. Thus 11.3% (73) of children with a GCS of 15 at the scene had deteriorated by the time their GCS was recorded in ED. All 13 children who died had a GCS of ≤8 at the scene. GCSs≤14 had a PPV of 71% (191/269) for GCSs≤14 on admission (table 3).

DISCUSSION

The consciousness level was documented in 90% of children admitted to hospital with head injury. Overall the majority of hospital and prehospital admissions had a GCS recorded. While this is in keeping with current NICE guidelines,[3] it was not universal practice and 30% of assessments reported in this study used either AVPU only or had no measure of conscious state recorded. The AVPU was most frequently used for infants <1 year old, while the GCS was used more frequently in older children. This finding is likely to be due to difficulties applying the GCS in infancy, despite the pGCS that is designed to account for these limitations.

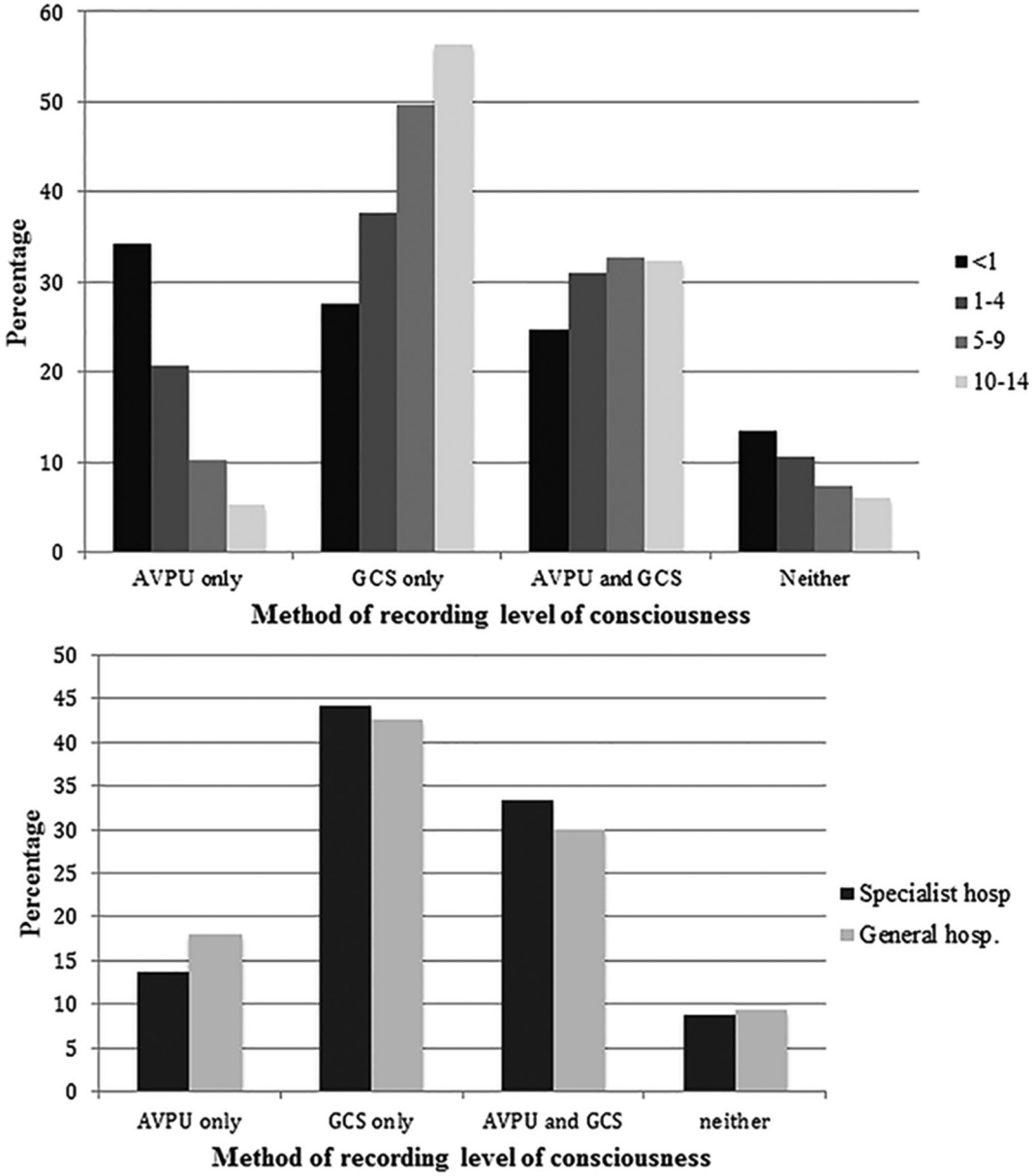

Figure 1 Proportion of children who had level of consciousness recorded and methods used in first hospital attended, by age group (<1, 1–4, 5–9, 10–14 years) and by specialist or general hospitals. (AVPU only: n=986; GCS only: n=2443; GCS and AVPU: n=1739; no recording: n=532, eight children excluded as age was not recorded.) GCS, Glasgow Coma Scale; hosp., hospital.

The use of the 'AVPU only' in infancy (<1 year) did not adversely affect the clinical management or diagnosis in terms of the proportion of children who had CT head scans undertaken and the diagnostic yield. Indeed, it could be argued that the AVPU=V/P/U was a more specific measure of serious head injury in this age group, as a significantly greater proportion of the children with a recorded AVPU=V/P/U had an ICI or a depressed fracture on CT scan when compared with cases where 'GCS only' was applied. However, among older children the GCS was a better predictor of an abnormal CT as in those with a GCS<14, significantly more children had a CT scan and significantly more of these scans were abnormal than when V/P/U only was recorded. The level of consciousness is not the only factor to influence the decision to undertake a CT scan.[3] This study confirms that an estimated 1 in 5–10 children with no impaired consciousness had an abnormality on CT. Influential factors for the same series of children are described further in Kemp *et al*.[16] However, these results would support the inclusion of AVPU as an acceptable initial measure of level of consciousness in infants and support a recommendation that a CT scan should be undertaken if AVPU=V/P/U.

The AVPU is simple, but none of the components are clearly defined. When considering the theoretical equivalence of AVPU to the components of the GCS, there is a range of total GCS that could be equivalent to each AVPU component. The definitions of eye opening scores (E1-4) can be directly related to the AVPU responses. However, an Alert child could be equivalent to a GCS of 15 or 14 as

Table 2 The number and proportion of children who had a CT scan when either an 'AVPU only' (n=986) 'GCS only' (n=2443) or both scores (n=1739) were recorded in ED and number and proportion of ICI or depressed fractures in those who had head CT

		Children (n)	No % who had CT with 95% CI	Unknown	No % (95% CI) of those who had CT with ICI or depressed fracture
<1 year of age					
AVPU n=375	Alert	358	63 17.6% (14% to 21.9%)	3	15/63 23.8% (15% to 35.6%)
	V/P/U	17	7 41.2% (21.6% to 64%)	0	7/7 100% (64.6% to 100%)
GCS n=301	15	269	59 21.9% (17.4% to 27.3%)	5	13/59 22% (13.4% to 34%)
	<15	32	17 53.1% (36.5% to 69.1%)	0	5/17 29.4 (13.3% to 53.1%)
AVPU and GCS n=270	Alert/GCS=15	247	59 23.9% (19.0% to 29.6%)	1	6/59 10.2% (4.8% to 20.5%)
	Discrepant scores Alert/GCS<15 (n=14) or GCS 15 and V/P/U (n=2)	*16*	*5* *31.3% (14.2% to 55.6%)*		*2/5* *40% (11.8% to 76.9%)*
	V/P/U: GCS<15	7	5 71.4% (36.0% to 92.0%)		5/5 100% (56.6% to 100%)
>1 year					
AVPU n=610	Alert	581	108 18.6% (15.6% to 21.9%)	5	10/108 9.3% (5.1% to 16.2%)
	V/P/U	29	13 44.8% (28.4% to 64.5%)	0	0/13 0% (0% to 22.8%)
GCS n=2138	14–15	1964	630 32% (30% to 34.2%)	29	78/630 12.4% (10% to 15.2%)
	<14	174	145 83.3% (77.1% to 88.1%)	1	44/145 30.3% (23.4% to 38.3%)
AVPU and GCS n=1466	Alert/GCS=14 or 15	1338	406 30.7% (28.3% to 33.2%)	15	31/406 7.6% (5.4% to 10.6%)
	Discrepant scores Alert/GCS<14 (n=27) or GCS 14 or 15/and V/P/U (n=39)	*66*	*42* *63.6% (51.6% to 74.2%)*	*0*	*3/42* *7.1% (2.5% to 19.0%)*
	V/P/U: GCS<14	62	45 72.6% (60.4% to 82.1%)	0	18/45 40% (27% to 54.6%)

Italics highlight the results were there was discrepancy between GCS and AVPU scores.
*Eight children excluded as age was unknown (one from AVPU group and four from GCS group, three from group with both scores).
ED, emergency departments; GCS, Glasgow Coma Scale; ICI, intracranial injury; P, responsive to painful stimulus; U, unresponsive; V, responsive to verbal stimulus.

they may be Alert but confused and have a verbal score of V4, however a verbal response would only be detectable in >5 year where the unmodified GCS is advised. An Unresponsive child should score an E1 and V1, however the motor response may include M3 as they may be decorticate or decerebrate. Therefore, the theoretical range for U could be a GCS 3–5.

It is less easy to align Verbal or Pain responsive categories of AVPU to GCS component scores due in part to the difference in pGCS and adult GCS. While the GCS component descriptors for the <5 year olds are more specific than for the older age group in terms of responsiveness there is still considerable scope for matching against different scores. For example, a child <5 years who responds to pain may score E2 for eye opening, V2-V3 for a verbal score and M2-5 for motor, that is, a total score between 6 and 10 while for a child >5 years the corresponding scores could be E2, V2-V5, M2-M5 totalling a score between 6 and 12. These wide ranges are reflected in the study results. Due to the large variability of V/P on

Table 3 GCS at the scene and in the ED for 911 children where both were recorded

GCS ED	≤8	9–12	13–14	15	Total GCS at scene
GCS scene					
15	4	5	64	570	643
13–14	4	13	81	56	154
9–12	8	16	11	8	43
≤8 or died	38	12	7	14	71
Total GCS in ED	54	46	163	648	911

Shaded values, highlight where the GCS was the same in at the scene and in ED.
ED, emergency departments; GCS, Glasgow Coma Scale.

the GCS, the AVPU is not sufficiently precise to closely monitor neurological deterioration.

Table 4 lists published studies that compare GCS with AVPU scores. The majority support a clear correlation between Alert and GCS=15 and Unresponsive with GCS=3 with a wider range of associated GCS scores for responsive to Pain or Voice. There are only two smaller paediatric studies.[17 18] The most recent of which evaluated the use of AVPU in the prehospital setting to identify children who might require intubation or intensive care and concluded that an AVPU of A or V identified 100% of children with a pGCS of or exceeding eight, and therefore, at low risk of requiring intubation or intensive care treatment.[18]

GCS is a composite scoring system of three components which share no relationship and there are many clinically plausible score combinations.[19] It is important to remember that the total GCS cannot be seen as a static and exact scale like the simpler scores and it should be used to measure change in each of its components with the total score to track the progress and consciousness of a patient. This emphasises the need for correct practice using the score, stating the component scores alongside total GCS on every communication and documentation as recommended by NICE. In this study only 75.4% of GCS scores had the component scores listed. This, however, does not take away the validity of using the total score as a guideline for the clinical management, that is, when a CT scan is recommended or appropriate airway intervention and the involvement of an anaesthetist.[3]

Prehospital GCS is a reasonable indicator of GCS in EDs and may be helpful in determining which children are at risk of serious head injury and require direct transfer to major trauma facilities, either in isolation or as part of a composite tool to be used in such situations.

However, for one in four children the GCS will change by the time they reach ED and ongoing monitoring with GCS in the prehospital period including all component scores is essential.

This study is the largest one to explore the equivalence of AVPU to GCS in children admitted to hospital with head injury, and the only one that attempts to compare the outcome for the two scoring systems in terms of investigations and diagnostic yield of serious cranial and ICI. The findings

Table 4 Previously published studies and equivalence of GCS and AVPU

		A	V	P	U
Mackay[13] n=174,730 Ambulance transfers to emergency departments Age>5 years	Most common score (range)	15 (9–15)	12 (5–14)	8 (4–13)	3 (3–7)
McNarry[20] n=1000 Neurosurgical patients All ages	Median score	15	13	8	6
Kelly[21] n=1384 Hospital admissions for poisoning All ages	Median (IQR)	15 (15)	13 (12–14)	8 (7–9)	3 (3)
Raman[17] n=159 Paediatric patients admitted to paediatric intensive care unit Age 2 months–12 years	Median (IQR)	14 (12–15)	11 (10–12)	6 (5.5–8)	3 (3–4)
Hoffman[18] n=302 Children prehospital emergencies multiple diagnoses Age<10 years	Median (IQR)	15 (15)	12 (10–13)	8.5 (6–10)	3 (3)
Nuttall (2018) n=5700 Age 5–15 years	Median (IQR)	15 (15)	13 (12–14)	11 (8–12)	3 (3–5)

are limited by its retrospective and multicentre design that may have impaired data completeness and variation in data quality between centres. Data were extracted from hospital case notes and while there may have been administrative errors that explained outlying results, clinical governance should ensure a level of accuracy within the case notes. We were unable to follow-up children who did not have CT and identify potentially missed cases of ICI or depressed fracture. While it was stated that measures were taken at the same point in the care pathway, we cannot be sure that temporal differences did not have an effect. Study numbers in this field will always be limited by the lower numbers of children with severe loss of consciousness, however this represents the real-world epidemiology of head injury where the majority of cases seen are minor head injuries.

CONCLUSION

Despite the current NICE guidelines, 25% children with head injury did not have a GCS recorded in the ED rising to 40% of prehospital cases. This study found that the equivalence of AVPU to GCS varied between children <5 years and >5 years. The use of AVPU alone at the initial hospital assessment in infancy did not adversely affect the rate of initial neuroradiological investigation or diagnostic yield. When used in isolation in older children it predicted a lower rate of CT imaging and lower diagnostic yield. We would recommend that use of the simple AVPU is beneficial to initial assessment of infants with head injury but is not sensitive enough to monitor change in levels of consciousness and would, therefore, not be recommended for ongoing monitoring of clinical status in this age group.

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Contributors AN: Medical student who undertook some of the data analysis and ran a second check on the statistical analysis undertaken by KMP. AN was lead author and contributed to the manuscript and undertook a literature search. KMP: Biosciences student undertook the primary data analysis, literature search and wrote the first draft of the paper. AMK: Principal investigator on the overall analysis of the dataset, supervised the student participation in the project. Edited, checked and finalized the final draft.

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Competing interests None declared.

Patient consent Not required.

Ethics approval The project was approved by the Central Manchester Research Ethics Committee (Ref 09/H1008/74) and was registered with hospital R&D or clinical governance departments in the participating hospitals. Approvals were renewed when the project was transferred to Cardiff University for analysis and updated in July 2012 (Ref 09/H1008/74).

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Data sharing statement Primary data-set has been destroyed subject to HQIP requirements.

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