

The utility of post-traumatic skull X-rays

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SUMMARY

During two 12-month periods, 12 395 accident and emergency department attenders with head injury were collected. Those characteristics which were significantly more common in head-injured patients who had skull fractures on X-ray were identified. These characteristics were: recent alcohol consumption in adults, initial unconsciousness, amnesia of any duration, vomiting, neurological signs, injuries sustained by pedestrians, motorcyclists and cyclists. Such characteristics were then further examined and their power as diagnostic tests for the presence of skull fracture on X-ray was detailed. In individual patients and especially in children, these characteristics were generally of little value in identifying patients with fractures. It was considered that, in the majority of individual patients with head injuries, accurate clinical diagnosis of radiologically apparent fractures was not possible. In view of this and in the light of the known risks in patients with fractures, it was concluded that skull X-rays should continue to be used relatively freely in the management of these patients.

INTRODUCTION

Following articles by Bell & Loop (1971) and Roberts & Shopfner (1972), there has been worldwide interest regarding the place of skull X-ray in the management of patients with head injury. Publications have appeared from Australia (De Campo & Petty, 1980), Canada (Harwood-Nash *et al.*, 1971; Cordon, 1981), Denmark (Anderson, 1978), Finland (Tunturi *et al.*, 1982), the United Kingdom (Boulis *et al.*, 1978; Eyes & Evans, 1978; de Lacey *et al.*, 1980; Jennett, 1980; Royal College of Radiologists, 1980, 1981, 1983; Gibson, 1983) and the United States (de Smet *et al.*, 1979; Phillips, 1979; Cummins *et al.*, 1980; Masters, 1980; Leonidas *et al.*, 1982; Larsen & Koziol, 1979). Such articles have provoked both a lively correspondence and editorial comment, but

revealed a dichotomy of opinion. On the one hand, radiologists believe that skull X-rays are over-used in head-injured patients, rarely affect management decisions, rarely show positive findings and are generally wasteful of resources (Bell & Loop, 1971; Roberts & Shopfner, 1972; Eyes & Evans, 1978; Royal College of Radiologists, 1981; Phillips, 1979; Masters, 1980). The opposing view, usually expressed by neurosurgeons and accident surgeons, is that plain skull films are indispensable in that they help to identify patients at risk from complications such as intracranial haematoma (Jennett, 1980; Galbraith, 1976; Galbraith, 1973; Mendelow *et al.*, 1983; Briggs *et al.*, 1984) or infection (Miller & Jennett, 1968; Jennett & Miller, 1972; Sande *et al.*, 1980, Briggs, 1974), and may allow the identification of patients requiring admission who would otherwise be discharged (Jennett, 1980; Mendelow *et al.*, 1983; Briggs *et al.*, 1984) or, conversely, allow the safer discharge of patients who might otherwise be admitted (Jennett, 1980; Mendelow *et al.*, 1983; Briggs *et al.*, 1984). It has also been suggested that half or more of radiologically apparent skull fractures are missed by accident and emergency (A & E) staff (de Lacey *et al.*, 1980; Gibson, 1983). The present article examines both the usefulness of skull X-rays and the accuracy of radiological diagnosis by A & E staff as well as suggesting which A & E attenders with head injury should be selected for X-ray.

MATERIAL AND METHODS

All A & E attenders with head injury during two 12-month periods were collected. The earlier study was retrospective and the later study prospective. During both study periods, head injury was defined according to the presence of one or more of the following:

- (1) a history of a blow to the head, with or without a period of unconsciousness or amnesia;
- (2) external evidence of injury to the head;
- (3) skull X-rays were taken;
- (4) head injury instructions were issued.

This definition approximates to rubrics N800–804, N850–854, N870–873, N900, N910, N918–921, N925, N929, N950 and N951 of the International Classification of Diseases (ninth revision). Patients with epistaxis or foreign bodies in the eye, ear or nose were excluded unless they fulfilled the criteria as, with the same proviso, were patients with burns. Patients with facial injuries, including fractures of the mandible, were generally included since they usually fulfilled the definition criteria. All patients with head injury who were brought in dead were excluded as were all patients dying at the scene, certified there and taken directly to the mortuary. All other attenders who fulfilled the definition criteria were included whether they were X-rayed or not. For each attender undergoing skull X-ray, the X-ray report by the A & E doctor was compared with that by the radiologist.

There was no significant difference between the two study groups in the numbers definitely having a particular characteristic, for example, knock out and amnesia, therefore, for statistical analyses, patients for whom there was no record of the presence

or absence of a particular characteristic were counted as not having that characteristic. Statistical significance was determined using Yates' chi-squared test. In addition, specificities, sensitivities, Youden's indices, relative risks and positive predictive values were calculated.

RESULTS

During the retrospective study there were 5768 A & E attenders with head injury and during the prospective study 6685 attenders. Excluding those brought in dead, the total number of patients was 12 395. Skull X-rays were performed in 5484 patients (44%). A skull fracture or diastasis was present in 206 patients or 3.8% of those X-rayed. Depressed fractures, mostly compound, occurred in 19 cases (9.2% of fractures). Pneumocephalus was found in only four patients (0.03% of all attenders) but all four had radiologically evident skull fractures. During the prospective study, the presence of clinical signs of skull fractures (CSF leak, bilateral bruising of the upper eyelids etc.) was noted. Such features occurred in 49 patients (0.7% of all attenders) and 28 of these patients had radiologically demonstrated fractures.

The frequency of various characteristics among all attenders and among patients with skull fractures on X-ray is shown in Table 1. Those characteristics which were significantly more common in patients with fractures are further defined in Table 2. Initial unconsciousness occurred in 61% of cases with fractures but only 6.6% of all patients initially knocked out had a fracture on X-ray. Similarly, neurological signs were present on initial examination in 43% of patients with skull fractures but only 14% of all attenders with signs had a radiologically proven fracture. Initial unconsciousness, amnesia of any duration, vomiting and signs, singly or in any combination, occurred in 147 (71%) of the patients with skull fractures. Thirty-four of the remaining 59 patients with radiologically proven fractures but none of the former characteristics were children, 16 being up to 12-months old. This age difference between those with and those without any or all of these four features was significant. Among all attenders, initial unconsciousness and amnesia became commoner as age increased whereas vomiting was twice as common in children as in adults; neurological signs were slightly commoner in children. Skull fractures on X-ray were significantly less likely to occur in attenders who had been assaulted, however, such cases accounted for 5.3% of all fractures seen on X-ray.

Acute post-traumatic intracranial haematomas occurred in 11 patients with a total of 14 lesions between them: four extradural haematomas, two patients with both extradural and subdural lesions, two with subdural haematomas alone, one with subdural and intracerebral haematomas, and two with intracerebral haematomas alone. Eight of these patients had a skull fracture on X-ray, two more had fractures clinically and the remaining patient, an 11-year-old boy, had no skull fracture. Thus, there was a highly significant association between radiologically proven fractures and the presence of an acute haematoma. The relative risk of a patient with a skull fracture developing an acute haematoma on X-ray was 164 times that of a patient without a fracture. For a patient with a fracture of the skull diagnosed radiologically and/or clinically, the risk was 296 times greater.

Table 1 Comparison of the frequency of various characteristics in all A & E attenders with head injury and in attenders with skull fractures

Characteristic	All patients (<i>n</i> = 12 395) (%)	Patients with skull fracture (<i>n</i> = 206) (%)	Significance of difference ¹
Age: 0-14	42.6	43.2	N.S.
15-64	50.9	48.5	N.S.
65 +	6.5	8.3	N.S.
Male	67.6	68.0	N.S.
Alcohol (adults)	10.1	17.9	****
Knocked out	15.2	60.7	****
Amnesic	7.1	20.4	****
Vomited	7.0	25.7	****
Signs	4.9	42.7	****
Assault	10.8	5.3	**
Industrial	5.8	6.8	N.S.
Sport	6.6	4.4	N.S.
Fall	34.8	32.0	N.S.
Fall bike	4.8	5.8	N.S.
Pedestrian	2.3	13.1	****
Cyclist	1.0	5.3	****
Motorcycle rider	2.5	4.9	N.S.
Pillion passenger	0.4	1.5	N.S.
Car driver	5.5	6.8	N.S.
Front-seat passenger	2.8	1.9	N.S.
Rear-seat passenger	2.0	1.0	N.S.
Other cause	15.0	9.2	**
Not recorded	5.7	1.9	*
All motor cyclists	2.9	6.3	***
All vehicle occupants	10.3	9.7	N.S.
All R.T.A.'s	16.6	34.5	****

¹ N.S.: not significant. * *P* less than 0.05.
 ** *P* less than 0.025. *** *P* less than 0.01.
 **** *P* less than 0.0005.

The skull X-ray reports by the A & E doctor for those patients with a radiologically proven fracture are shown in Table 3. During the retrospective study, two patients with skull fractures were incorrectly thought to have a fracture of the ipsilateral orbit and a prominent vascular marking, respectively. The skull X-rays were considered entirely normal by the A & E medical staff in less than 10% of patients with skull fractures. No attempt was made to assess the acceptability of the films for diagnostic purposes.

DISCUSSION

The clinical diagnosis of a fractured shaft of femur or Colles' fracture is relatively easy. Similarly, the clinical suspicion of a fracture of the wrist or ankle is often confirmed

Table 2 Statistical indices for those factors which are significantly more common in patients with skull fractures

Characteristic	Specificity	Sensitivity	Youden's index	Relative risk	Positive predictive value
Alcohol (adults)	0.99	0.18	0.16	1.97	0.03
Knocked out	0.86	0.61	0.46	9.16	0.07
Amnesic	0.93	0.20	0.13	3.45	0.05
Vomited	0.93	0.26	0.19	4.81	0.06
Signs	0.96	0.43	0.38	16.63	0.14
Pedestrian	0.98	0.13	0.11	7.06	0.10
Cyclist	0.99	0.05	0.04	5.82	0.09
Motorcyclist	0.97	0.06	0.03	2.29	0.04
All R.T.A.'s	0.84	0.34	0.18	2.17	0.03

Table 3 Accuracy of skull X-ray report by Accident Unit staff

Year	Accident officers' report				Totals
	Fracture (%)	Fracture? (%)	Other positive (%)	No bony injury (%)	
1976-1977	76 (85)	3 (3.4)	2 (2.2)	8 (9.0)	89
1979-1980	100 (85)	6 (5.1)	—	11 (9.4)	117
Totals	176 (85)	9 (4.4)	2 (1.0)	19 (9.2)	206

radiologically. The diagnosis of a fracture of the distal phalanx of a finger, the nasal bones or a toe does not determine management, and many would agree that X-rays in such circumstances are redundant. Likewise, the radiological search for an isolated rib fracture is considerably less important than the search for a pneumothorax in the same patient, so that a chest X-ray rather than oblique rib films is, if anything, all that is required. Certain clinical diagnosis of a skull fracture is only possible in 0.7% of A & E attenders with head injury. Moreover, almost half of such patients with definite skull fractures clinically do not have a fracture on their plain X-rays. In the remaining 99% of head injury attenders, the presence or absence of a skull fracture cannot be determined clinically, although the likelihood of a fracture being present can be gauged as more or less likely. This overwhelming majority of head injury attenders, in whom the presence or absence of a skull fracture cannot be determined, includes the majority (76%) of patients shown to have a skull fracture radiologically. Since demonstrating the presence of a skull fracture is of undoubted significance to clinicians (Briggs, 1974; Briggs *et al.*, 1984; de Lacey *et al.*, 1980; Galbraith, 1973, 1976; Jennett & Miller, 1972; Jennett, 1980; Larsen & Koziol, 1979; Mendelow *et al.*, 1983; Miller & Jennett, 1968; Sande *et al.*, 1980), one must ask how else the fracture can be diagnosed other than radiologically. In fact, it is surprising, in view of the impossibility of making the diagnosis clinically in 99% of cases, that only about half of all A & E attenders with head injury undergo skull X-ray examination. Further evidence of the impossibility of making a certain diagnosis

of skull fracture is provided by the report of the Royal College of Radiologists (1980). In this study, 27% of skull fractures were not clinically suspected prior to X-ray and one in eight of all skull fractures occurred in cases in whom the doctor was clinically *certain* that no fracture was present. It is not unusual for (experienced) doctors to find a skull fracture on X-ray when they had little apparent reason for suspecting such a finding or even to X-ray the patient. Such surprises are more likely in children. In one large paediatric series, 39% of children with a skull fracture on X-ray had either no external evidence of head injury (28%) or else such evidence was contralateral (11%) (Harwood-Nash *et al.*, 1971). In another children's series, the authors concluded that there was no correlation between symptoms, physical findings and the likelihood of skull fracture (Boulis *et al.*, 1978), a view shared by Roberts & Shopfner (1972). In a post-mortem series of selected patients, 20 (39%) of 51 cases with wholly or predominantly unilateral fractures did not have corresponding external evidence of injury (Adams *et al.*, 1980). Thus, there is ample evidence that certain clinical diagnosis of the presence or absence of a skull fracture is impossible in the overwhelming majority of individual A & E attenders with head injury. Nevertheless, various reports, including this one, have shown that certain characteristics are significantly more common among *groups* of patients with skull fractures on X-ray and have grouped these characteristics together as a high-yield list (Bell & Loop, 1971; Boulis *et al.*, 1978; Cordon, 1981; Cummins *et al.*, 1980; De Campo & Petty, 1980; de Smet *et al.*, 1979; Masters, 1980; Phillips, 1979; Tunturi *et al.*, 1982). These authors then advocate that only those head injury attenders with one or more of the high-yield characteristics should undergo skull X-ray examination, thereby reducing the number of skull X-rays performed. However, implementing such lists may lead to up to 61% of skull fractures being missed (De Campo & Petty, 1980). This high failure rate would not be acceptable to clinicians: indeed, when such lists have been introduced, non-compliance by the clinicians dealing with patients first hand has been high (Cordon, 1981; Cummins *et al.*, 1980; de Smet *et al.*, 1979; Phillips, 1979); 80% or more of patients X-rayed not fulfilling high-yield criteria (Phillips, 1979; Cummins *et al.*, 1980). Cummins (1980) investigated the reasons for non-compliance and concluded that these were neither perverse nor irrational but that they were highly discretionary, and not attributable to ignorance of head injury or the methods used for its evaluation. Failure of high-yield lists to identify fractures was most likely in children (de Smet *et al.*, 1979), a finding confirmed in the present study.

The characteristics identified from the present study as being significantly more common among *groups* of patients with skull fractures are generally those also identified by other workers. However, none of these characteristics were capable of accurately identifying those *individuals* who did have a fracture on X-ray, i.e. low sensitivity. Their poor performance as diagnostic tests was reflected also in their low Youden's index. Rejecting all A & E attenders, prior to history-taking and examination, as not having a fracture would be surprisingly accurate—98.3% correct—but 206 patients with fractures would be left at considerable risk. Sheps & Schechter (1984) stated that the clinical utility of diagnostic tests is critically determined by the positive and negative predictive values. The positive predictive values of the characteristics referred to above are universally low in the present study (Table 2). Therefore, by this criterion, the characteristics commonly included in high-yield lists also fail as diagnostic tests for the

presence of skull fracture not even being redeemed by a negative result effectively excluding the presence of a fracture since none had a negative predictive value equal to 1. Also in the present study, one group of patients was significantly less likely to have a skull fracture, i.e. those assaulted, yet nobody would suggest that because of this no assaulted patient should be X-rayed, although this is effectively what a high-yield list would advocate.

Radiologists often imply that because few skull X-rays show the presence of a skull fracture this investigation is of little value (Bell & Loop, 1971; Boulis *et al.*, 1978; De Campo & Petty, 1980; de Lacey *et al.*, 1980; Evans, 1977; Eyes & Evans, 1978; Masters, 1980; Phillips, 1979; Roberts & Shopfner, 1972; Royal College of Radiologists, 1980, 1981, 1983). However, a low positive yield from an investigation does not necessarily mean that such an investigation is worthless. In the case of skull fractures, there is no practical way in the majority of individual cases of diagnosing the presence or absence of a fracture except radiologically. For the clinician, knowing that a skull fracture is present or absent has important implications (Briggs, 1974; Briggs *et al.*, 1984; Galbraith, 1973, 1976; Jennett, 1980; Jennett & Miller, 1972; Mendelow *et al.*, 1983; Miller & Jennett, 1968; Sande *et al.*, 1980).

Another common misconception amongst radiologists is that all A & E attenders with head injury have a skull X-ray (Boulis *et al.*, 1978; Evans, 1977; Eyes & Evans, 1978; Masters, 1980; Phillips, 1979). In the present study, less than half of head injury attenders underwent skull X-ray examination. In Scotland, only 58% underwent this investigation (Strang *et al.*, 1978) and, in Newcastle, 62% (Maitra, 1981), the same proportion as in Dumfries (Welch, 1983), whilst in an adult population 65% were X-rayed (Swann *et al.*, 1980).

It has often been alleged that the skull X-ray appearances all too infrequently affect management decisions (Anderson, 1978; Evans, 1977; Eyes & Evans, 1978; Masters, 1980; Phillips, 1979; Roberts & Shopfner, 1972). This allegation is not supported by the authors' findings. For example, in one of the latter studies, five of eight patients with a skull fracture on X-ray had their management altered by the finding of a fracture (Eyes & Evans, 1978). In another, an unstated number were admitted to hospital solely on the basis of finding a fracture (Roberts & Shopfner, 1972) and admission in such cases was a management decision. Failure to appreciate that admission for observation is a form of management was also evident in Phillips' study (1979). In this latter study, 76% of patients with fractures had their management altered by the finding of a fracture. In a further study, it seemed accepted practice that 49% of patients with skull fractures would be discharged from the A & E department (Masters, 1980), but such practice would not be acceptable in Britain. This latter study also clearly demonstrated the significant relationship between skull fractures and outcome, despite the authors' conviction that he had demonstrated the absence of any significant relationship. In the present study, 47 patients (23% of those with fractures) were admitted because of the finding of a fracture on X-ray, 30 of these were children, no fewer than 12 being in the first year of life.

Medico-legal considerations are also often thought to contribute to unnecessary requests for skull X-ray, although the proportion of requests attributed to these reasons is very variable (Bell & Loop, 1971; Boulis *et al.*, 1978; Cordon, 1981; Cummins, 1980; de Lacey *et al.*, 1980; Eyes & Evans, 1978; Roberts & Shopfner, 1972; Royal College of

Radiologists, 1980), but the only reasons for selecting patients for (skull) X-ray after injury are medical; if no medical reason exists, there can be no legal reason for an X-ray. It behoves doctors to agree the medical indications for a skull X-ray. The recommendations as to which patients should be X-rayed should be based on careful consideration of the evidence available and agreed by A&E specialists, who see large numbers of mild head injuries and who accept initial clinical responsibility for these patients.

In the study reported here, radiological diagnosis by A & E staff was correct in 85% and in less than 10% with skull fractures on X-ray were the films considered entirely normal by the A & E staff. Twelve of the 19 patients in the latter group had none of the clinical characteristics: knock out, amnesia, vomiting or signs. Of the two patients misdiagnosed radiologically, one had none of these features and the other had only vomited. The accuracy of radiological diagnosis displayed here is similar to that in an adult series (88%) (Swann *et al.*, 1980) and much better than in two other series (de Lacey *et al.*, 1980; Gibson, 1983). Sample sizes in the latter two series were small, only four (de Lacey *et al.*, 1980) and 10 (Gibson, 1983) patients having skull fractures on X-ray, of which, 50 and 60% were missed, respectively. Generalizations based on these latter two papers are, therefore, not justified.

In view of the cogent reasons for X-raying patients and, in the light of the foregoing discussion, it is suggested that the following groups of head injury attenders should have skull X-rays:

- (1) all children with a history of or external evidence of injury to the head;
- (2) any patient with neurological signs, whether attributed to alcohol or not;
- (3) those patients with clinical signs of a skull fracture;
- (4) all patients with lacerated wounds of the scalp, in whom penetration is possible;
- (5) any patient initially knocked out or amnesic;
- (6) patients with significant symptoms following a head injury.

In addition, skull X-ray should be considered in head-injured patients not included in the above categories but who have:

- (a) other injuries warranting admission in their own right;
- (b) other conditions by themselves dictating admission.

Applying such indications would mean that about three-quarters of all head injury attenders would undergo skull X-ray rather than the present 60%.

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