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A 100 year review of the evolution in neurosurgical thinking regarding compound depressed skull fractures

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Introduction

This review was conducted by performing a PubMed search of the English literature with search words “skull fracture; compound skull fracture; compound depressed skull fracture; skull fracture assault” and synonyms thereof. The review is divided into three sections in an effort to compartmentalize, for the purpose of ease of understanding, the evolution in neurosurgical thinking that has occurred over the last century regarding a fundamental neurosurgical topic namely compound depressed skull fractures. Firstly the early work by the pioneers in Neurosurgery such as Harvey Cushing, Cannaday and Coleman will be discussed, many of whose principles are still applicable today. The second section will look at the literature on the subject as taken from the second half of the twentieth century. The final section will look at papers published in the last fifteen years.

A Historical Perspective- the early 20th century

A review of the largely historical English literature regarding the subject of the management of compound fractures finds at the very beginning a series of papers regarding largely orthopedic injuries. Wilkinson, 1924, reported a series of fifty-four patients in whom their compound fractures were closed primarily. This study reported a six percent sepsis rate [1]. Cannaday in 1929 reported on one hundred patients with compound fractures that include both compound cranial as well as compound limb fractures. These wounds were closed primarily and the study reports a ten percent sepsis rate [2].

Cannaday in a later paper, 1940, describes how North American neurosurgeons have developed a technique for the management of compound skull fractures involving the instillation of local anesthetic, adequate antisepsis, and debridement followed by wound closure without drainage [3]. Cannaday compares the disciplines of Orthopedics and Neurosurgery and although he admits that he understands that the scalp has a rich blood supply which aids it to combat infection in comparison to other areas of the body, he finds it difficult to understand why the difference in location should make any difference to the mode of treatment of the compound skull fracture and the compound limb fracture. He proposes the same approach as that described above with regards compound skull fractures of the limbs, as being applicable to compound fractures in general. Cannaday reinforces his viewpoint by sequentially listing over twenty surgeons of the time, each afforded a paragraph, giving each surgeon’s viewpoint on the subject of the primary closure of compound skull fractures, all of which reinforce his own. Many of these opinions offer a short series with sepsis rates ranging between five and ten percent. The references provided in this paper give the Surgeon’s name with whom Cannaday communicated and admit the data collected is through personal communication [3].

Pfeiffer and Smyth, 1936, [4] criticize Cannaday’s 1929 paper [2] and conclude that immediate closure of a compound fracture should be avoided unless the surgeon is capable of adhering to extremely careful surgical technique best conducted under general anesthesia [4]. Pfeiffer and Smythe, 1936, point out the disaster of premature wound closure which creates an anaerobic environment ideal for the proliferation of clostridial species and the subsequent gas gangrene that develops leading to significant morbidity and mortality [4].

Coleman, 1941, a Neurosurgeon of the time, emphasizes the importance of the operative management of compound skull vault fractures [5]. His viewpoint opposes that of the previous surgeons as he states the benefits of early operative intervention under general anesthetic as absolutely critical in terms of preventing sepsis. He motivates this viewpoint to prevent sepsis and thereby mortality, cerebral scarring and post traumatic epilepsy. Coleman emphasizes formal operative intervention within 8 hours of injury and proposed its application to all compound skull fractures. The degree of this intervention ranged from simple disinfection and suture of the scalp laceration over a linear fracture to the other extreme whereby debridement of scalp, bone, dura and brain was necessary. Coleman emphasized the fact that the neurosurgical patient was often non co-operative and thereby unsuitable for adequate wound care under local anesthetic. He explains the antibiotic therapy of the time to be sulfanilamide powder that was dusted onto the wound six-hourly and thought not to harm brain tissue. Coleman emphasizes the primary means for preventing infection to be the operative intervention with a lesser benefit being afforded by non-directed antimicrobial therapy. The best chance of preventing infection would hence be through early thorough operative intervention and this is what Coleman is emphasizing [5].

Coleman [5] refers to the work by Harvey Cushing, 1917 [6], whom demonstrated the effectiveness of using anesthesia together with the mechanical removal of contamination by voluminous application of non-irritant solution to the compound skull wound as was performed by him during the first World War[6]. Coleman, 1941, states that the unconscious patient does not require any anesthesia other than local anesthesia instillation into the wound for satisfactory surgical management [5].

Carmody, 1942, looked at 1411 patients admitted for head injuries of which forty-two percent, were compound skull fractures [7]. He refers to the work of Coleman, 1941 [5] and emphasizes important variables in the prevention of sepsis regarding compound skull fractures [7]. The first and what Carmody considered the most important variable that needed to be considered was the actual surgical intervention performed [7]. Coleman, 1941, had emphasized the importance of preventing sepsis through the wide debridement of damaged scalp tissue often leading to a significant defect [5]. En-bloc excision of the skull fracture in its entirety was then performed by four burr holes placed at right angles shaping a rectangle around the fracture [5].

These burr holes are then linked by a rouguer with the block of fractured skull bone being excised and discarded [5]. Any dural breech was opened and damaged brain removed by suction debridement. Significant blood loss was commonly encountered and temporary intra-operative packing and subsequent slow removal as brain re-expansion occurred was the technique employed for hemorrhage control. In this paper particular mention is made of the fact that cautery was not employed [5].

Carmody, 1942, put forward as acceptable a more conservative operative approach in the prevention of compound skull fracture sepsis [7]. He emphasized the importance of a preparatory phase which he considered as more important than the operative approach. Carmody, 1942, puts as his emphasis this phase and emphasizes the importance of time before operative intervention [7]. He draws on the work of Cushing from World War One and notes the optimum time to be within twenty-four hours [6;7]. Beyond this twenty-four hour window Cushing had demonstrated there is an increased incidence of infection no matter how adequately the surgical procedure was performed [6].

Coleman 1941, from a Neurosurgical perspective, emphasizes the importance of early copious irrigation as shown by Cushing, 1918, but further emphasizes radical scalp, skull, and brain, debridement as fundamental in preventing the devastating consequences of central nervous system sepsis [5;6]. Little mention is made of neurological outcomes from this approach in his paper. Finally Carmody, 1942, emphasizes that time from injury to operative intervention as the critical factor and not the operative intervention itself [7].

Almost fifty years go by after this early work and little is added to these principles. While this is not to say there is no refinement through locally directed antimicrobial use, improved radiological and hematological interventions, as well as improved operative interventions , the foundations of management afforded by these early Neurosurgeons still forms the basis of present day thinking regarding compound depressed skull fracture management.

A Contemporary perspective- the late 20th century

Wylen et al, 1997, looked at a series of fifty-two patients with compound depressed skull fractures over a period of five years from 1991-1996 in Louisiana, North America [8]. This study was looking specifically at comparing the sepsis rates between the traditional approach of elevating the fracture and doing a craniectomy of the fracture site and a delayed cranioplasty, with the intervention of primarily replacing the fracture fragments into the fracture site after washing these fragments. In this study the interventional group (fracture fragments replaced primarily) had antibiotic therapy instituted within twenty-four hours of injury and their operative procedure was performed within seventy-two hours. The study reports a zero percent sepsis rate with this approach [8].

Meirowsky, 1965, in data taken from the Korean War experience, noted a decrease in the infection rate of compound cranial wounds from 41% to 1% when the surgical facilities were moved closer to battle zones permitting early debridement occurring on average within forty-eight hours of injury [9]. In this Korean War study operative intervention, comprising simple wound irrigation, debridement, and wound closure, was performed largely under local anesthetic cover. This study reports a one percent sepsis rate. Injuries necessitating dural repair and debridement of herniating brain tissue were conducted under general anesthesia in these same temporary hospitals [9].

Braakman, 1972, looked at a series of one hundred and eighty five patients with compound depressed skull fractures in whom the decision to administer antibiotic prophylaxis was at the surgeon's discretion. His study concluded that there is no difference in the infection rate whether antibiotics were administered or not as long as surgical intervention was employed within 24 hours of injury. Braakman reported a four percent sepsis rate in this series [10].

Rathore, 1991, in a review of the English literature published between 1970 and 1989, reviewed eight hundred and forty eight cases of Patients with compound fractures [11]. Five hundred and nineteen received antibiotics with a four percent incidence of meningitis. The remaining three hundred and twenty nine patients did not receive antibiotics and the incidence of meningitis was 3%. Rathmore concluded that antibiotics are not useful in preventing meningitis with regards a compound skull fracture [11].

Gustillo and Anderson 1976, writing from an Orthopedic perspective, in a review of one thousand and twenty five compound long bone fractures point out the fact that what is commonly termed prophylactic cover is in fact a misnomer [12]. They point out the fact that within sixty five percent of their patients the deep tissues of these compound fracture wounds were in fact contaminated by the injury through exposure to the environment and hence the antimicrobial therapy is not prophylaxis, but rather treatment of contamination [12].

A South African study done at Baragwanath Hospital by Demetriades et al, 1992 [13], notes that most centers provide antibiotic prophylaxis for between three and fourteen days post injury. At Baragwanath Hospital these antibiotics are started in the Casualty department and are administered for three days. This study conducted in the late 1980's randomized one hundred and fifty seven patients with compound skull fractures into three treatment groups. Group A made up of forty six patients received no antibiotics; Group B made up of fifty patients received ceftriaxone for three days; Group C made up of sixty one patients received ampicillin and sulphadiazine for three days. The study concluded that the overall incidence of infectious complications in the non-antibiotic group was significantly higher than in the antibiotic group, eight percent versus one percent, with the p value being < 0.05 [13].

The importance of timely antibiotic therapy is further reinforced by Harley et al, 2002 [14], writing from their work done regarding compound limb fractures, whom conclude that delayed surgical management of compound fractures has not been found to carry an associated increased risk of infection as long as the patients received early antibiotic therapy [14].

In referring back to the study by Demetriades et al, 1992 [13], the authors, in considering the controversy on the subject, aptly conclude that it is feasible that certain sub-groups of patients with skull fractures will benefit from antibiotic prophylaxis. For this reason they suggest that all compound skull fractures are afforded prophylactic antibiotic therapy[13].

In considering the antibiotic selection the principles outlined in the study by Demetriades, 1992 [13], done in a South African setting, are firstly that the cover should include that for gram positive organisms, and commonly a first generation cephalosporin should be used. The cover should secondly include that to cover gram negative organisms by the addition of an aminoglycoside. Finally the regimen should provide anaerobic cover through the use of a penicillin or metronidazole [13]. This viewpoint on the empiric selection of specific antibiotics used is shared by Zalavras [15].

In considering the length of antibiotic therapy Gopal and Lipschitz, 1988, in an earlier South African Baragwanath study, advocated 10-14 days of prophylaxis [16]. Charalampos 2005 [15] points out that in the United States an average of three days is generally advocated. An additional three days of antibiotics is recommended if any surgical procedure is conducted at the fracture site [15].

The dangers of prolonged antibiotic therapy was illustrated by Ignelzi, 1975, whom randomized ten patients to receive either antibiotics or no antibiotics as prophylaxis for compound fracture care [17]. Cultures of the posterior nasopharynx at day 10 revealed the presence of more resistant organisms in the patient group that received antibiotics compared with cultures taken from the patient group that did not receive antibiotics [17].

Demetriades et al, 1992, [13] in his Baragwanath Hospital study, takes note of this risk and states that the three day prophylaxis used at Baragwanath Hospital is unlikely to cause resistance problems [13]. His study criticizes the earlier study at Baragwanath Hospital by Gopal and Lipschitz, 1988, that proposed the ten to fourteen days of prophylaxis [16]. Demetriades et al, 1992, points out that this long duration of therapy is probably unnecessary, is expensive, and which carries the further risk of breeding antimicrobial resistance [13].

A Recent perspective- the 21st century

In considering a PubMed review of the English Literature on the subject of skull fractures that included only studies conducted in the last decade and a half, two important trends are seen emerging that have become even more pronounced in those studies conducted in the last five years. The first of these is that several recent papers now have the patient numbers to focus on one specific mechanism of injury for example traumatic brain injury secondary to only machete injuries or only firearm injuries. This enables an improved understanding of more specific injury patterns and outcomes that are etiology specific. The second trend seen is the use of National Computerized Trauma Registries in countries such as the United States of America and Australia from which data is taken and studies conducted. Studies that make use of National Registries from which to draw data is virtually non-existent in studies published prior to the year 2000. These National Trauma Registries enable an analysis of huge numbers of patients across multiple centers and thereby provide impressive results.

Looking at these recent studies Rehman et al, 2007, looked at sepsis rates in compound skull fractures in fifty-six patients [18]. This study identifies dural breech and comminution as risk factors for an increased sepsis rate. A statistically significant difference in the sepsis rate was revealed if the patient presented more than eight hours after trauma. This finding puts further emphasis on the importance of early operative intervention which although traditionally put forward as necessary within twenty four hours to prevent sepsis, should, according to Rehman, 2007, be even earlier than this. The sepsis rate in this study was five percent [18].

Bell et al. challenges the traditional principles in the management of compound frontal sinus fractures and retrospectively looked at an impressive one hundred and forty four patients managed at his institution from 1995-2005 [19]. Bell et al, 2007, confirms the traditionally important variables in the management of these injuries namely anterior table displacement; posterior table displacement; integrity of the nasofrontal duct and dural integrity as essential considerations [19]. Sixty-six of the one hundred and forty-four patients considered in this study had undisplaced frontal sinus fractures and were managed conservatively, as is standard Neurosurgical practice [19]. Of the remaining patients whom were managed operatively, twenty-nine formed the interventional study group and these had open reduction and fixation of the anterior table alone with preservation of the sinus mucosa, while twenty-one patients underwent the traditional cranialization of the frontal sinus and meticulous stripping of the frontal sinus mucosa [19]. Bell et al, 2007, reports no statistically significant difference in the sepsis rates between the interventional and control groups [19]. While no statistically significant difference in the sepsis rate between the two groups was found, Bell, et al 2007, did report a sixteen percent complication rate in the operative group as a whole which included sepsis and mucocoele development, the two feared complications of leaving the frontal sinus mucosa in place [19].

Aurangzeb et al, 2015, considered only the linear skull fracture and published his findings on 144 patients admitted to his hospital from 2011-2012 [20]. This study specifically looked at the incidence of extradural hemorrhage (EDH) in association with a linear skull fracture so as to evaluate the need for computerized tomography in patients with this fracture pattern [20]. Aurangzeb et al. reported a thirty-four percent incidence of EDH in linear skull fractures in general, however this incidence is seventy-four percent in parieto-temporal linear skull fractures [20].

Enicker, 2014, in a South African Study from the University of KwaZulu Natal, considered one hundred and eighty- five patients over a ten year period whom were managed for head injuries secondary to a machete/bush knife [21]. In this study seventeen percent of patients presented with wound sepsis secondary to late presentation and/or referral from regional hospitals. The other findings in this study were that ninety-three percent of patients were male with a mean age of thirty-one years [21].

Moussa and Abbas, 2016, considered low velocity penetrating head injury in sixteen patients split evenly in etiology between assault and motor vehicle accidents [22]. This study utilizes the Glasgow Outcome Score (GOS) was the chosen measurement tool and interestingly sixty-two percent of patients in this study had a Glasgow Outcome Score of five [22].

Firearm injuries are addressed in a study by Chattopadhyay, 2010, whom examined ninety-one head injury cases secondary to assault of which forty-four percent were firearm injuries [23]. A similar study by Seleye-Fubara, 2011, considered sixty-eight deaths from severe head injuries of which firearm injuries constituted twenty-four percent [24]. Both studies confirm head injuries secondary to firearm injuries to not only be increasing in prevalence at their centers, but both confirm these injuries carry the highest mortality [23; 24].

Pilgrim et al, 2014, looked specifically at fatalities secondary to a single knock-out punch in Australia over a twelve year period from 2000-2012 [30]. This study utilized the National Coronial Information System in Australia and identified ninety cases over the study period. Pilgrim et al, 2014, noted an alarming seventy-three percent of cases involved the use of alcohol [25]. What the study found was that alcohol increased the subject's chance of being the aggressor as well as the victim [25].

Irie et al, 2011, in another Australian Study conducted by utilizing the Queensland Trauma registry from 2005-2007, considered the incidence of traumatic extra dural hemorrhage (EDH) in patients aged 0-24 years [26]. Of the two hundred and twenty-four patients with traumatic EDH, seventeen percent were due to assault. While this is less than twenty percent, what is important to note is the strong association between EDH and skull fractures which were present in seventy-five percent of patients with EDH [26]. This supports the study by Aurangzeb et al, 2015, conducted in Abbottabad, whom considered only linear skull fractures (see above), and had a similar result of seventy-four percent [20].

Long et al, in a seven year study conducted in Wales and published in 2016, considered the impact of socioeconomic stratification relative to the risk of suffering a traumatic head injury secondary to assault that required admission [27]. The study noted firstly that with reference to inter-personal violence, a head injury was the most common indication for patient admission [27]. This study furthermore found geographical clustering that indicated a statistically significant higher risk existed for residents of the poorest communities when compared with the more affluent communities [27]. The study also found a higher risk associated with individuals living in cities and towns compared to villages [27].

Schwed et al, in a recent North American study published in 2016, identified variables in 201 patients diagnosed mild traumatic brain injury that could be used as predictive outcome markers [28]. This study noted that being younger, having a post resuscitation GCS score of 15/15, and on imaging having at most an isolated subarachnoid hemorrhage were three important variables that found statistical significance in predicting a favorable outcome [28]. This study suggests that these variables can be used to decide whether this patient group can safely be managed outside of the Intensive Care Unit [28].

It is however in a North American study that utilized the North American National Electronic Injury Surveillance System-All injury Program, published by Gaw and Zonfrillo, 2016 [29], that the true value of a National Computerized Data capturing system can be appreciated. The paper considered data captured from Emergency Department visits for head trauma between 2007 and 2011, and considered a staggering 10,746,629 visits during the study period. What was noted is that the incidence of head trauma increased by sixty percent over the study period with the largest increases seen in children below eleven years of age and in adults over sixty-five years of age. In fact 16, 9% percent of head trauma secondary to assault occurred in children below the age of seventeen [29]. In considering the mechanism of injury involved in the assaults as recorded by Gaw and Zofrillo, 2016, multiple assailants were the most common mechanism of injury occurring in thirty-eight percent of cases [29].

Further findings of this study were that sixty-six percent of assault-related head trauma victims were male and that thirty-eight percent of this group were between the ages of 24-44 years [29].

In conclusion the last 100 years have seen several trends in the literature on the subject of compound depressed skull fractures. The first of these is a gradual shift away from preventing sepsis as the primary focus which dominates in the early papers on the subject. A second trend observed is an increasing interest in the epidemiology of patients rather than just focusing on the compound depressed skull fracture pathology itself. Considering the contemporary papers very specific topics are now being investigated and from this unique conclusions are able to be made. In the last 10 years we note something very specific namely the inclusion of data from national trauma registries and as such the study subject numbers show enormous increases.

Declaration

We the authors listed below declare that this article has not been published previously, nor is it under consideration for publication elsewhere, and that, if accepted, will not be published elsewhere in the same form, in English or in any other language, without the written consent of the publisher

Conflict of Interests

None of the authors listed above have any financial nor personal relationships with other people, or organizations, that could inappropriately influence (bias) their work, all within 3 years of the beginning the work submitted.

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