Functional Outcomes in Moderate-to-Severe Traumatic Brain Injury Survivors

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Abstract

Introduction: We aimed to analyze the functional outcomes based on the admission characteristics in individuals with moderate-to-severe traumatic brain injury (TBI) over a 5-year period. Methods: A retrospective cohort study was conducted to assess the cognitive, physical, and functional outcomes based on traditional and novel metrics used in potential outcome prediction. Results: A total of 201 participants were enrolled with a mean age of 31.9 ± 11.9 years. Glasgow Coma Score (GCS) at emergency department did not correlate with the functional independence measure (FIM) score or Rancho Los Amigos (RLA) scores at discharge. The absolute functional gain was significantly higher in individuals who sustained TBI with RLA 4–5 (34.7 ± 18.8 vs. 26.5 ± 15.9, P = 0.006). Participants with RLA 4–5 on admission to rehabilitation showed good correlation with the absolute FIM gain. On multivariate regression analysis, only age (odds ratio 0.96; 95% confidence interval: 0.93–0.98; P = 0.005) was found to be the independent predictor of good functional outcome. Conclusions: Initial GCS is not a predictor of functional outcome in individuals who sustained TBI. Consideration of age and development of novel functional measures might be promising to predict the outcomes in individuals with moderate-to-severe TBI.

Keywords: Functional outcomes, rehabilitation, traumatic brain injury

Introduction

Traumatic brain injury (TBI) is a major cause of morbidity and mortality among young adults.1,2 It has been estimated that about 235/100,000 Europeans are thought to be hospitalized or died from TBI annually.3 However, the heaviest burden is shouldered by low- and middle-income countries.4 An earlier study observed an increasing burden of head injuries in Qatar due to rapid industrialization and motorization among all ages.5 In addition, the frequency of TBI is higher among young adults; of them, 25% sustained severe injuries with an overall mortality rate of 11%.6

Among TBI survivors, the functional disability possesses a physical and fiscal burden on families and societies. TBI is a heterogeneous disease in terms of injury mechanism, pathology, severity of injury, and prognosis; although most studies attempted to evaluate this diverse population with uniform interventions.7,8 For better clinical management, it is imperative to predict the short and long-term functional outcome after TBI. For this reason, many investigators have utilized statistical tool to develop outcome prediction models which combine two or more important variables for accurate prognosis.9 Most of the outcome prediction studies utilized combination of demographic, clinical, and radiological characteristics. Survivors of moderate-to-severe TBI typically experience impaired physical, cognitive, and social abilities depending on the injury severity.10 An earlier study showed that age, Glasgow Coma Score (GCS), and initial functional independence measure (FIM) score at rehabilitation are independent prognostic tool for a 1-year outcome post-injury.11

Despite the fact that multiple prognostic models for TBI have been developed over the years, none of them is widely used across different settings.9,12 The vast majority of studies have focused on acute outcomes in individuals who sustained TBI, but intermediate functional outcome among TBI survivors

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is relatively explored less. Data supporting early prediction of meaningful intermediate functional outcomes after TBI based on initial injury parameters are scarce in our region. In Qatar, there exist an opportunity to study a large cohort of patients treated for moderate-to-severe head injuries. Herein, the present study analyses the functional outcomes based on admission characteristics in moderate-to-severe TBI cases.

**Methods**

A retrospective observational cohort study was conducted for all individuals with moderate to severe TBI that were admitted to the designated Level I Trauma Center at a tertiary care hospital between January 2010 and December 2014. The admission data were extracted from the hospital trauma registry database, and the information on post-acute functional outcomes was obtained from the Department of Physical Medicine and Rehabilitation (PMR) at the referral hospital. The Institutional Review Board at Medical research center (IRB#15051/15) has approved this study with a waiver of informed consent. The study was reported according to the STROBE checklist.

**Acute trauma care**

On admission to emergency department (ED), participants were assessed, resuscitated, and managed in accordance with the advanced trauma life support guidelines. This study included only TBI patients who survived and transferred to rehabilitation services. Individuals with moderate TBI were those who had initial GCS between 9 and 12 and severe TBI was referred to those with admission of 8 or lower. Computed tomography (CT) information was available for all individuals. Data included patients demographics (age, gender, and nationality), mechanism of injury, prehospital scene time, vital signs at the scene and on admission, injury severity score (ISS), head injury severity, GCS (scene and on admission), abbreviated injury scores (AIS), intubation, CT scan findings, repeat CT scan, type of TBI (the intracranial lesions), associated injuries, ethanol intoxication status, neurological interventions, hospital and Intensive Care Unit (ICU) length of stay (LOS), ventilatory days, and in-hospital complications.

**Rehabilitation services**

The rehabilitation services have been provided by the Department of PMR at a large urban referral Hospital in Qatar. The service is provided through the spectrum of care (acute and subacute). In the acute setting, this service is provided by the early intervention rehabilitation team (EIRT) which was initiated in 2008. The EIRT physician provides consultation at the acute care facility (HGH) and performs detailed patient assessment and initiates referral to rehabilitation services (physical therapy, occupational therapy, and speech therapy). After assessment, the EIRT physician conducts a case conference and plans the interdisciplinary rehabilitation program to focus on early mobilization, cognitive facilitation, and prevention of complications. Once the individual is clinically stable to follow simple commands, the EIRT physician triages the individuals and who fit the criterion for in-patient rehabilitation transferred to TBI neuro-rehabilitation unit (subacute) at the referral hospital. In this unit, the primary objective is to provide comprehensive and state of the art rehabilitation services. Patients were initially evaluated for cognition and function to provide goal-directed interdisciplinary rehabilitation. Screening and assessment include outcome measures such as revised Rancho Los Amigos (RLA) scale, FIM score, Absolute Functional gain, FIM efficiency, disability scale, mobility scale, Berg Balance Scale, Mini–Mental status examination (MMSE), and 10 m walk test. The inpatient rehabilitation LOS was also documented.

**Assessment measures**

The RLA Scale measures the levels of awareness, cognition, behavior, and interaction with the environment after TBI. Level I – no response (total assist) to Level X – purposeful, appropriate (modified independent). The FIM scores are a combined physical and cognitive measure which ranges from 18 to 126. It evaluates 18 items (13 motor and 5 cognitive) with 1 point (total assistance) to 7 points [fully independent]. The difference between FIM at admission and FIM at discharge from inpatient rehabilitation is the actual functional gain or FIM gain and is a measure of functional recovery. FIM efficiency is defined as FIM gain divided by number of days in hospital. It reflects the mean gain in scores per day. The functional limitations based on FIM Score have been divided into three groups as high (FIM score <40), moderate (FIM 40–79), and low (FIM ≥80). Based on RLA score, patients were categorized as severe (RLA 4–5), moderate (RLA 6–7), and low (RLA ≥8) injury severity.

**Statistical analysis**

Data were presented as proportions, medians, or mean ± standard deviation, as appropriate. FIM scores at admission and at discharge, absolute functional gain, and FIM efficiency were analyzed according to severity of head injury (head AIS <3 vs. ≥3) and GCS (GCS ≤8 vs. >8). We compared the FIM score on admission with the FIM at discharge from rehabilitation. We also evaluated RLA score on admission with respect to the absolute functional gain. Correlation of initial GCS at ED with FIM and RLA score (discharge from rehabilitation) and absolute functional gain was analyzed using Pearson’s correlation coefficient. Furthermore, correlation between head AIS and RLA level at discharge was analyzed. Predictors of good functional outcome (FIM ≥80) at discharge from rehabilitation were sought by multivariable regression analysis and data were expressed by odd ratio (OR) and 95% confidence interval (CI). All data analyses were carried out using the Statistical Package for the Social Sciences version 18 (SPSS, Inc., Chicago, IL USA).

**Results**

During the study period, a total of 7500 individuals were admitted to the trauma center, of them 201 (2.7%) sustained moderate-to-severe TBI and were initially stabilized and
treated under acute trauma care and later transferred to the rehabilitation service. The mean age of participants was 31.9 ± 11.3 years and all of them were males [Table 1].

The overall mean ISS was 24.4 ± 8.5 and head AIS was 3.8 ± 0.9. All individuals sustained moderate-to-severe TBI based on their hospital GCS on admission. The GCS at discharge from the rehabilitation unit was relatively higher as compared to the GCS on trauma unit admission. However, discharge from the inpatient rehabilitation unit was based on the final GCS, FIM score, and overall functional status of the individual which were ideally assessed by the rehabilitation unit team. With respect to the types of brain lesion as reported on the initial CT scanning, brain contusion was the most common finding (73.5%), followed by subarachnoid hemorrhage (38%), subdural hemorrhage (37%), and epidural hemorrhage (24%). Initial CT imaging data were available for the entire enrolled individual in this analysis. Brain edema was reported in 29% of individuals and diffuse axonal injury was observed in 20% individuals.

Endotracheal intubation was needed in 92% of the cohort; ICP monitoring was required in 29.4%, while 26 (12.9%) participants had external ventricular drainage insertion. Neurosurgical interventions such as craniectomy and craniotomy were performed in 13.4% and 11.9% cases, respectively. The median length of acute care hospital stay was 30 (6–223) days; ICU stay was 16 (2–126) days, followed by median stay in the rehabilitation unit of 43 (2–443) days.

Table 2 describes the neurologic and functional outcome measures in individuals who sustained TBI based on the clinical assessments’ on admission and at discharge from rehabilitation unit. The standard measures of neurological rehabilitation include the RLA scale and FIM instrument. With respect to the admission RLA scale (RLA VI 31.3%), patients at discharge showed improved cognitive functions with higher RLA scores (RLA VIII 66.2%). Furthermore, the overall functional disability in terms of median FIM percentage improved considerably from admission (FIM 49 [14–100]) to discharge (FIM 90 [14–100]) from rehabilitation. Figure 1 compares the admission neurological status as per the RLA scale with the median absolute functional gain. There is a significant association among the initial functional status (RLA 4–5) with higher median absolute functional gain as compared to other groups (P = 0.01). The GCS at ED was negatively correlated with the absolute functional gain (r = −0.154; P = 0.03) during rehabilitation.

A total of 193 participants sustained severe TBI based on head AIS (≥3). Furthermore, the FIM score revealed a marked positive improvement in individuals presented with severe TBI as initially 36.8% had a high disability (FIM <40) on admission which reduces to 5.7% at discharge from the rehabilitation. Similarly, the proportion of cases with low disability (FIM ≥80) increased from 8.8% on admission to 68.4% at discharge. The mean absolute functional gain in individuals who sustained severe TBI was 32.4 ± 18.5. The

Table 1: Demographics, clinical presentation, head injury lesions, interventions, and complications in TBI patients required rehabilitation (n=201)

| Variables                                    | Values |
|----------------------------------------------|--------|
| Age (mean±SD)                                | 31.9±11.3 |
| Males, n (%)                                 | 201 (100) |
| Expatriates, n (%)                           | 186 (92.5) |
| Qatari nationals, n (%)                      | 15 (7.5)  |
| Mechanism of injury, n (%)                   |        |
| Motor vehicle crashes                        | 65 (32.3) |
| Fall from height                             | 55 (27.4) |
| Pedestrian                                   | 48 (23.9) |
| Fall of heavy object                         | 9 (4.5)   |
| Motorcycle crash/bike                        | 11 (5.5)  |
| Assault                                      | 7 (3.5)   |
| Others                                       | 6 (2.9)   |
| Scene time                                   | 25.5±16.6 |
| EMS time                                     | 65.1±27.4 |
| Systolic blood pressure ED                   | 131±22   |
| Diastolic blood pressure ED                  | 80±17    |
| Pulse pressure ED                            | 101±27   |
| Oxygen saturation ED                         | 97.3±5.6 |
| GCS scene                                    | 8.9±3.9  |
| GCS ED                                       | 5.7±3.9  |
| GCS on discharge from rehabilitation         | 14.6±0.7 |
| Head AIS                                     | 3.8±0.9  |
| ISS                                          | 24.4±8.5 |
| Head injury lesions, n (%)                   |        |
| Brain contusion                              | 139 (73.5) |
| Skull fracture                               | 118 (65.6) |
| Subarachnoid hemorrhage                      | 65 (38.2) |
| Subdural hemorrhage                          | 61 (37)   |
| Epidural hemorrhage                          | 38 (23.8) |
| Brain edema                                  | 49 (29.3) |
| Pneumocephalus                               | 39 (24.2) |
| Diffuse axonal injury                        | 33 (20.4) |
| Extra-axial hemorrhage                       | 19 (12.0) |
| Intraventricular hemorrhage                  | 18 (11.5) |
| Intracerebral hemorrhage                     | 4 (2.6)   |
| Intra-hemispheric hemorrhage                 | 1 (0.7)   |
| Intubation, n (%)                            | 185 (92.0) |
| Interventions, n (%)                         |        |
| ICP monitor insertion                        | 59 (29.4) |
| External ventricular drainage                | 26 (12.9) |
| Cranietomy                                   | 27 (13.4) |
| Craniotomy                                   | 24 (11.9) |
| Complications, n (%)                         |        |
| Pneumonia                                    | 91 (51.7) |
| Sepsis                                       | 26 (16.5) |
| ARDS                                         | 3 (2.0)   |
| ICU LOS                                      | 16 (2-126) |
| Ventilatory days                             | 9 (1-27)  |
| Acute LOS                                    | 30 (6-225) |
| Rehabilitation LOS                           | 43 (2-443) |

ED: Emergency department, ICU: Intensive care unit LOS: Length of stay, ARDS: Acute respiratory distress syndrome, SD: Standard deviation, EMS: Emergency medical service, GCS: Glasgow coma score, AIS: Abbreviated injury scores, ISS: Injury severity score, ICP: Intracranial pressure, SD: Standard error
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Table 2: Neurologic physical therapy outcome measures in traumatic brain injury patients admitted to rehabilitation department

| Measure                                    | On admission, n (%) | At discharge, n (%) |
|--------------------------------------------|---------------------|--------------------|
| RLA scale (n=198)                          |                     |                    |
| Level II: Generalized response: Total assistance | 3 (1.5)             | 1 (0.5)            |
| Level III: Localized response: Total assistance | 5 (2.5)             | 2 (1.0)            |
| Level IV: Confused/agitated: Maximal assistance | 21 (10.6)           | 4 (2.0)            |
| Level V: Confused, inappropriate nonagitated: Maximal assistance | 36 (18.2)           | 3 (1.5)            |
| Level VI: Confused, appropriate: Moderate assistance | 62 (31.3)           | 17 (8.6)           |
| Level VII: Automatic, appropriate: Minimal assistance for daily living skills | 40 (20.2)           | 31 (15.7)          |
| Level VIII: Purposeful, appropriate: Stand-by assistance | 31 (15.7)           | 131 (66.2)         |
| Level IX: Purposeful, appropriate: Stand-by assistance on request | 0                  | 7 (3.5)            |
| Level X: Purposeful, appropriate: Modified independent | 0                  | 2 (1.0)            |
| FIM percentage                             | 49 (14-100)         | 90 (14-100)        |
| FIM score                                  | 62 (18-126)         | 113 (18-126)       |
| Disability scale                           |                     |                    |
| 0: well                                    | 1 (0.5)             | 9 (4.5)            |
| 1: Minor symptoms not affecting lifestyle  | 5 (2.5)             | 59 (29.8)          |
| 2: Disable but independent in self care    | 24 (12.0)           | 77 (38.9)          |
| 3: Disable with up to moderate assistance  | 57 (28.5)           | 29 (14.6)          |
| 4: Maximal assistance                      | 53 (26.5)           | 14 (7.1)           |
| 5: Total assistance                        | 60 (30.0)           | 10 (5.1)           |
| Mobility scale                             |                     |                    |
| 0: Bedridden/wheelchair bound              | 45 (22.5)           | 23 (11.7)          |
| 1: Sits without support                    | 29 (14.5)           | 47 (23.9)          |
| 2: Walk with the help of another person    | 29 (14.5)           | 22 (11.2)          |
| 3: Walks with aid                          | 13 (6.5)            | 19 (9.6)           |
| 4: Walks 5 meter without aid              | 27 (13.5)           | 28 (14.2)          |
| 5: Able to walk 200 m outside              | 57 (28.5)           | 58 (29.4)          |
| Berg balance scale (median, range)         | 10.5 (0-52)         | 49 (0-56)          |
| Not done                                   | 116 (59.2)          | 43 (21.8)          |
| 0-20 (Poor: wheelchair bound)             | 45 (23.0)           | 15 (7.6)           |
| 21-40 (Fair: Ambulatory with assistance)   | 20 (10.2)           | 26 (13.2)          |
| 41-56 (Good: independent)                  | 15 (7.7)            | 113 (57.4)         |
| MMSE                                       | 16 (1-30)           | 26 (2-30)          |
| Not done                                   | 48 (23.9)           | 13 (6.6)           |

Table 2: Contd...

| Measure                                    | On admission, n (%) | At discharge, n (%) |
|--------------------------------------------|---------------------|--------------------|
| 27-30: normal cognitive function           | 13 (6.5)            | 76 (38.6)          |
| 21-26: mild cognitive function             | 31 (15.4)           | 67 (34.0)          |
| 11-20: moderate cognitive function         | 80 (39.8)           | 35 (17.8)          |
| 0-10: Severe cognitive function            | 29 (14.4)           | 6 (3.0)            |
| Ten meter walk test done                   | 42 (21.1)           | 163 (83.2)         |
| Ten meter walk test (s)                    | 14 (6-36)           | 8 (5-90)           |

RLA: Ranchos los amigos, FIM: Functional independence measure, MMSE: Mini–Mental state examination

Figure 1: Comparison of Ranchos Los Amigos score on admission to rehabilitation with the absolute functional gain (P = 0.001)

initial GCS at ED did not correlate with FIM score (r = 0.038, P = 0.59) or with RLA scores at discharge (r = 0.063, P = 0.38) from rehabilitation unit. However, a significant negative correlation has been observed between head AIS and RLA score at discharge (r = −0.216; P = 0.002).

Table 3 shows the disability levels (FIM score) on admission and at discharge which looks at the rate of recovery according to the initial GCS at ED. On admission, individuals with severe TBI (GCS ≤8) had significantly higher rate of disability (FIM <40), i.e., 42% versus 22%, P = 0.03. The severity of TBI did not differ significantly with respect to the disability rate at discharge. Moreover, the absolute functional gain was significantly higher in participants with RLA 4–5 (34.7 ± 18.8 vs. 26.5 ± 15.9, P = 0.006) as compared to the other groups. Furthermore, more number of severe TBI cases (63.3% vs. 46%, P = 0.03) had clinically significant FIM efficiency (>0.6 points/day) than moderate injury cases.

Table 4 compares the functional disability (FIM score) on admission and at discharge from rehabilitation. On admission to the rehabilitation, the functional assessment of TBI patients revealed high (FIM <40), moderate (FIM 40–79), and low disability (FIM ≥80) to be in 74 (36.8%), 110 (54.7%), and 17 (8.5%) cases, respectively. Among the 74 TBI cases with
a high disability at admission, 31 (42%) cases had a good recovery with low disability post-rehabilitation.

On the other hand, the different categories of RLA scores on admission to rehabilitation and at discharge did not differ significantly among the individuals with initial severe TBI based on their admission GCS [Table 5].

**Multivariate regression analysis for the predictors of good functional outcome**

Relevant variables in terms of age, systolic blood pressure at ED, ISS, head AIS, admission GCS, intubation and craniotomy/craniectomy were used in multivariate regression analysis for functional outcome (FIM ≥80) at discharge from rehabilitation. The analysis showed that only age (OR 0.96; 95% CI: 0.93–0.98; P = 0.005) was the independent predictor of good functional recovery [Table 6].

**Discussion**

This cohort study evaluates the admission characteristics and functional outcomes in individuals sustained moderate-to-severe TBI from a rapidly developing Middle Eastern country that characterizes with high involvement of young individuals. Although previous data[8,14,15] suggested GCS as a predictor of unfavorable outcomes and mortality, the present study did not identify admission GCS as a reliable predictor of functional outcome. Instead, other parameters such as FIM could be a reliable tool to predict the individual functional outcome. Such finding warrants further investigations that implement such scoring system and to address the impact of FIM scoring on the early and late functional outcome of individual with TBI.

With respect to the epidemiological pattern, participants in our study cohort were younger in age (32 years) as compared to earlier studies.[11] Andriessen et al.[16] reported higher mean age among severe (46 years) and moderate (50 years) TBI individuals. This difference in participants’ age among studies could be related to the mechanism of injury. It has been shown that falls emerge frequently as an important cause of injury in certain populations.[17] Elderly individuals experienced falls as the primary pattern of injury in other studies.[7] In moderate-to-severe TBI cases, the extent of brain damage by itself could sufficiently determine and explain differences in the functional outcome and neurological recovery.[4]

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| GCS ≤8 (n=150), n (%) | GCS 9-12 (n=50), n (%) | P |
|-----------------------|------------------------|---|
| **On admission (FIM score)** | | |
| High disability (<40) | 63 (42.0) | 11 (22.0) | 0.03 for all |
| Moderate disability (40-79) | 76 (50.7) | 33 (66.0) |
| Low disability (≥80) | 11 (7.3) | 6 (12.0) |
| FIM total | 47.4 ± 22.0 | 56.9 ± 19.3 | 0.007 |

| At discharge (FIM score) | | |
| High disability (<40) | 10 (6.7) | 1 (2.0) | 0.33 for all |
| Moderate disability (40-79) | 35 (23.3) | 15 (30.0) |
| Low disability (≥80) | 105 (70.0) | 34 (68.0) |
| FIM total | 82.1 ± 20.3 | 83.5 ± 16.9 | 0.66 |
| AFG | 34.7 ± 18.8 | 26.5 ± 15.9 | 0.006 |
| FIM efficiency* | 0.94 ± 0.86 | 0.75 ± 0.68 | 0.15 |
| >0.6 units/day | 95 (63.3) | 23 (46.0) | 0.03 for all |
| ≤0.6 unit/day | 55 (36.7) | 27 (54.0) |

AFG: Absolute functional gain, FIM: Functional independence measure, LOS: Length of stay, GCS: Glasgow coma score. AFG=Discharge (FIM) - admission (FIM); FIM Efficiency = AFG/LOS (FIM efficiency reflects the mean gain in scores per day) *FIM efficiency >0.6 points/day are typically accepted as clinically significant, whereas a <0.6 unit/day change represents a poor rate of improvement

| Table 4: Comparison of functional disability (functional independence measure score) on admission and at discharge from rehabilitation |
|---|---|---|
| **At discharge** | **On admission to rehabilitation** | **P** |
| High disability (FIM <40) | Moderate disability (FIM 40-79) | Low disability (FIM ≥80) |
| On admission (FIM score) | (n=110; 54.7%) (%) | (n=17; 8.5%) (%) | |
| High disability (FIM <40) | (n=11; 5.4%) | 11 (14.9) | 0 | 0.001 |
| Moderate disability (FIM 40-79) | (n=51; 25.4%) | 32 (43.2) | 19 (17.3) | 0 |
| Low disability (FIM ≥80) | (n=139; 69.2%) | 31 (41.9) | 91 (82.7) | 17 (100) |
| FIM total | 47.4 ± 22.0 | 56.9 ± 19.3 | 82.1 ± 20.3 | 83.5 ± 16.9 | 0.66 |
| AFG | 34.7 ± 18.8 | 26.5 ± 15.9 | 82.1 ± 20.3 | 83.5 ± 16.9 | 0.006 |
| FIM efficiency* | 0.94 ± 0.86 | 0.75 ± 0.68 | 0.94 ± 0.86 | 0.75 ± 0.68 | 0.15 |
| >0.6 units/day | 95 (63.3) | 23 (46.0) | 95 (63.3) | 23 (46.0) | 0.03 for all |
| ≤0.6 unit/day | 55 (36.7) | 27 (54.0) | 55 (36.7) | 27 (54.0) | |

FIM: Functional independence measure
In our cohort, individuals with a high disability on admission showed improved cognitive functions at discharge from rehabilitation with higher FIM percentage and RLA scores. Consistent with our findings, Sandhaug et al. demonstrated significant improvement in the mean FIM total score from admission to discharge. Similarly, a Danish study reported improvement in functional outcomes of severe TBI cases at discharge from rehabilitation.

It is also evident from our findings that the relative neurological improvement was higher in the severe TBI participants, as evidenced by absolute functional gain and FIM Efficiency. Moreover, good functional recovery observed in up to 70% of individuals with TBI which was comparable among moderate and severe TBI cases.

The beneficial effect of early therapeutic intervention in individuals who sustained TBI is well established. Existing evidence suggested that early integration of rehabilitation right from the acute care improved overall recovery of TBI cases. Furthermore, León-Carrión et al. reported better global functioning at discharge in participants underwent early neurorehabilitation as compared to those received delayed treatment. Although, the rate of poor functional outcome was about 30%–40% depending on whether admission GCS or head AIS was considered. It is evident that intensive neurorehabilitation could result in better than expected outcomes for a large proportion of individuals, and that patients who benefit most from rehabilitation in terms of relative (although not absolute) recovery, are those who are more severely injured. Furthermore, our data confirm that the rate of absolute functional gain is better for injured patients with initial RLA 4–5.

The IMPACT and CRASH predictor models used a number of elements to determine global outcomes from TBI including the motor component of GCS (IMPACT) or the GCS total value (CRASH). However, in the present study, admission GCS did not correlate with either the FIM or RLA scales at discharge from the hospital. This could be explained by the fact that increasing use of sedative and muscle relaxant drugs during prehospital care may complicate the evaluation of ED GCS as there might be a chance of overestimation of the initial injury severity (lower GCS at hospital admission). In line with our findings, Zafonte et al. suggested that acute GCS has limited implications in predicting functional and cognitive recovery in individuals who sustained TBI. Rather, it may be a more useful tool for predicting posttraumatic mortality. Another investigator concluded that the predictive value of acute GCS should be carefully reassessed while constructing prognostic models for functional and cognitive outcomes among survivors of TBI to attain better recovery.

Kim suggested young age, motor vehicle crash victims, reactive pupil preoperatively, high GCS score on admission, and absence of acute brain swelling to be the independent predictors of good functional recovery. On multivariate analysis, predictors of good functional recovery included younger age, lower admission GCS, and lower head AIS. In summary, good functional recovery was noted in individuals with TBI who sustained moderate and severe TBI, as well as younger TBI group. Isolated mild TBI cases were excluded from our study due to the presence of early interval rehabilitation program in the rehabilitation setting which was contradictory to the research finding and evidence. Therefore, for inpatient rehabilitation as evident by earlier studies, Bender et al. suggested early interval rehabilitation program in improving the FIM scores at discharge which is interpreted in terms of better daily activities. Similarly, a case–control study demonstrated that younger TBI group showed a higher mean rate of functional recovery as compared to older age group. In our cohort, individuals with a high disability on admission showed improved cognitive functions at discharge from rehabilitation with higher FIM percentage and RLA scores. Consistent with our findings, Sandhaug et al. demonstrated significant improvement in the mean FIM total score from admission to discharge. Similarly, a Danish study reported improvement in functional outcomes of severe TBI cases at discharge from rehabilitation.

### Table 5: Ranchos Los Amigos scores based on the initial severity of traumatic brain injury (Glasgow Coma Score) at emergency department

| GCS ≤8 (n=147) (%) | GCS 9-12 (n=50) (%) | P |
|-------------------|-------------------|---|
| Admission RLA     |                   |   |
| ≤5                | 54 (36.7)         | 11 (22.0) 0.11 for |
| 6-7               | 73 (49.7)         | 28 (56.0) all |
| ≥8                | 20 (13.6)         | 11 (22.0) |
| Discharge RLA     |                   |   |
| ≤5                | 10 (6.8)          | 0 (0.0) 0.13 for |
| 6-7               | 36 (24.5)         | 11 (22.0) all |
| ≥8                | 101 (68.7)        | 39 (78.0) |

RLA: Ranchos los amigos, GCS: Glasgow coma score

### Table 6: Multivariate regression analysis for the predictors of good functional outcome (functional independence measure ≥80) at discharge from rehabilitation

| OR       | 95% CI  | P    |
|----------|---------|------|
| Age      | 0.96    | 0.93-0.98 | 0.005 |
| Systolic blood pressure | 0.99 | 0.98-1.01 | 0.55 |
| ED       |         |       | |
| ISS      | 0.97    | 0.92-1.02 | 0.25 |
| Head AIS | 0.85    | 0.57-1.27 | 0.44 |
| Admission GCS | 1.04 | 0.94-1.14 | 0.43 |
| Intubation | 0.79    | 0.19-3.20 | 0.74 |
| Craniootomy/cranectomy | 0.48 | 0.23-1.02 | 0.05 |

ED: Emergency department, ISS: Injury severity score, AIS: Abbreviated injury scores, GCS: Glasgow Coma Score

Prediction of functional outcome is a key element for the care and long-term management of individuals who sustained TBI. Prognostication can help in accurate health planning, family counseling, and implementation of effectiveness research interventions. An earlier study identified some level of disability as measured by Glasgow Outcome Scale Extended (GOSE 2–6) at 1-year post-injury in severe as well as moderate TBI survivors, emphasizing the serious and long-term consequences. In the present study, overall acute and rehabilitation LOS was relatively higher than those who were treated in acute inpatient TBI rehabilitation in Singapore. This could be explained by the fact that these investigators also included mild TBI cases which were discharged early as compared to severe TBI group.

For effective neurorehabilitation, it is important to correlate the severity of injury TBI with the functional outcomes. It has been reported that rehabilitation plays an important role in improving the functional outcomes at discharge. The FIM is the commonly utilized functional assessment tool for inpatient rehabilitation as evident by earlier studies. Bender et al. suggested early interval rehabilitation program in improving the FIM scores at discharge which is interpreted in terms of better daily activities. Similarly, a case–control study demonstrated that younger TBI group showed a higher mean rate of functional recovery as compared to older age group.
analysis, age was found to be the only independent predictor of good functional recovery in our cohort. Notably, our TBI cohort comprised of a relatively younger population which infers that functional recovery is expected to be much better in young adults. Consistent with our finding, another study suggested a higher rate of recovery in terms of disability at admission was seen in the young TBI survivors. Moreover, an earlier study suggested age and longer acute care stay to be important predictors of worst functional outcome which could be due to slow neurological recovery among elderly. Generally, there exists a potential for a higher rate of improvement in the young group than the elderly population.

Limitations
There are potential limitations to our retrospective study, not the least being that several patients were lost to follow-up. Especially those individuals deemed too ill for neurorehabilitation were transferred from rehabilitation to long-term care facility, and thus it was difficult to access their clinical progress. Furthermore, due to the nature of the transient expatriate population in Qatar, we were unable to assess the eventual outcomes at 6- or 12-month postinjury using GOSE or FIM scale. Loss to follow-up was partially explained by a relatively large group of expatriates included in our study; most of them had returned to their home country at the time of follow-up. As we intended to assess the functional outcomes, we enrolled only who survived to discharge with availability of the relevant data; therefore, the sample size to empower the study was not calculated. Sample size is one of the limitations of the present study.

Summary and Conclusions
In individuals with moderate-to-severe TBI, almost 70% of the individuals attained good functional recovery on early follow-up (3-month) and 30% still have a poor functional outcome at the time of discharge from rehabilitation. Participants with RLA 4–5 on admission to rehabilitation showed highest correlation with absolute FIM gain. Absolute functional gains are inversely correlated with admission GCS. Admission high head AIS is associated with poor functional outcome. Also, admission GCS is not well correlated with functional outcome as measured by the FIM instrument and is not an accurate predictor of outcome in participants with TBI. Consideration of age and development of novel functional measures might be promising to predict the outcomes in individuals who sustained TBI. The most severely injured individuals have higher rates of recovery and relative improvement; although poor absolute outcomes continue to be correlated with severity of TBI. Therefore, conventional admission indices of injury severity cannot be relied upon for functional outcome prediction in TBI. Novel functional measures show promise in being able to predict outcomes in TBI. Aggressive neurorehabilitation could result in significant improvements in even severely injured TBI participants. However, large cross-sectional studies are needed to assess the impact of early neurorehabilitation services on the intermediate and long-term functional outcomes in individuals who sustained TBI. Furthermore, 6- or 12-month postinjury follow-up is needed for the accurate assessment of eventual outcome which might identify the later functional recovery in other individuals. This will reflect the impact and cost of TBI on the public health and community as a whole.

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Conflicts of interest
There are no conflicts of interest.

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