Published in final edited form as:

Brain Inj. 2018 January 01; 32(9): 1103–1109. doi:10.1080/02699052.2018.1484165.

Does a regular Wessex Head Injury Matrix (WHIM) assessment identify early signs of infections in people with Prolonged Disorders of Consciousness (PDOC)?

SK Dhamapurkar¹, BA Wilson¹, A Rose¹, G Florschütz¹, P Watson², A Shiel³

¹OT Department, The Raphael Hospital, Kent, Tonbridge, UK

²MRC Cognition and Brain Sciences Unit, Cambridgeshire, Cambridge, UK

³OT Department, The National University of Ireland, Ireland, Galway

Abstract

Brain injury survivors are considered to be at high risk for infections. The infection and resultant cognitive deterioration is well established for people with dementia; however, to date, no investigation has been conducted for patients in prolonged disorders of consciousness (PDOC). This study sets out to examine whether the results of regular Wessex Head Injury Matrix (WHIM) assessments provide an indicator that might identify early signs of infections in PDOC patients. Both retrospective and prospective approaches were used. The retrospective study examined the WHIM scores of 21 patients and the prospective study examined the WHIM scores of 22 PDOC patients. The results indicated that WHIM total score decreased due to the infections in 17 of the 21 infection cases ($p < 0.001$) in the retrospective study and 15 ($p = 0.001$) of the 22 prospective infection cases. Patients in a Minimally Conscious State showed a bigger proportion of change between their baseline score and the scores taken at the pre-infection stage in both the retrospective and prospective studies when compared to the patients in a vegetative state. The findings of the study suggest the importance of serial WHIM assessments throughout the period of recovery not only to measure cognitive changes but also to highlight underlying physical changes such as infections that will impact on response to rehabilitation and recovery.

Keywords

Prolonged Disorders of Consciousness; Recovery; Infection; WHIM; Rehabilitation

Introduction

Patients with prolonged disorders of consciousness (PDOC) are those who remain in a state of wakefulness but absent (vegetative state (VS)) or reduced awareness (minimally conscious state (MCS)) for more than 4 weeks (RCP Guidelines on PDOC 2013). Following severe brain injury, many patients progress through the stages of coma, VS and MCS as they emerge into a state of full awareness. A minority remain in a vegetative or minimally

Conflicting Interests:

The authors report no conflicts of interest.

conscious state for the rest of their lives. The brain injury may result from any cause including traumatic brain injury, hypoxic damage or vascular accidents such as a stroke.

Medical complications are common after brain injury (Colbert et al 2016). The development of post stroke infection leads to neurological deterioration (Boehme et al 2013), may extend the hospital length of stay (George et al 2013), lead to poor functional outcome, increase the cost of care (Weimar et al 2002) and may result in death (Popovic et al 2013). Urinary tract infection (UTI) occurs frequently in dementia and after an acquired brain injury. It is associated with poorer outcomes with increased odds of decline in neurological status during hospitalisation (Rocco et al 2007), and death or disability (Dufour et al 2015, Aslanyan et al 2004 and Stott et al 2009).

Patient safety has become a cornerstone of care and preventing Healthcare Associated Infections (HCAI) has become a priority. It is estimated that 300,000 patients a year in England acquire a HCAI as a result of care within the National Health Service (NHS) (NICE guidelines infection control 2014). In 2007, Meticillin-Resistant *Staphylococcus Aureus* (MRSA) bloodstream infections and *Clostridium difficile* infections were recorded as the underlying cause of approximately 9000 deaths in hospital and primary care in England (National Audit Office 2009). HCAI are estimated to cost the NHS approximately £1 billion a year and £56 million of this is estimated to be incurred after individuals are discharged from hospital (National Audit Office 2009). In addition to increased costs, each one of these infections means additional use of NHS resources, greater patient discomfort and a decrease in patient safety (NICE guidelines infection control 2014). A no tolerance attitude is now in place in relation to avoiding HCAI.

HCAI can exacerbate existing or underlying conditions, delay recovery and adversely affect quality of life (NICE guidelines infection control 2014). Reducing all types of HCAI will help organisations to avoid the following costs related to these infections: drug therapy, hospital readmissions and potentially repeat procedures, decontamination, laboratory and imaging investigations, litigation, ward closures, medical, nursing and management time, increased community nursing/rehabilitation as a result of morbidity following HCAI, staff sickness and associated staff cover. In summary, infections can prolong hospital stays, create long-term disability, increase resistance to antimicrobials, represent a massive additional financial burden for health systems, generate high costs for patients and their family and cause unnecessary deaths (Prevention and control of HCAI costing report 2011). Thus, reduction in the rates and severity of infection are essential for cost savings and ensuring high quality care provision.

HCAI can occur across a wide range of clinical conditions and can affect patients of all ages and are caused by a wide range of microorganisms. These are often carried by the patients themselves, and have taken advantage of a route into the body provided by an invasive device or procedure. HCAI can occur in otherwise healthy individuals; especially if invasive procedures or devices are used e.g. indwelling urinary catheters are the most common cause of urinary tract infections and bloodstream infections are associated with vascular access devices (Loveday et al 2014).

Infection is a common cause of morbidity in the general medical population, but patients in PDOC are at an even higher risk of infection than other client groups. This is not only due to the fact that several devices may be in place such as a metallic plates (cranioplasty), urinary catheters, tracheostomy tubes, PEG tubes, indwelling catheters etc. but also due to their inability to communicate effectively or to express concerns. In the absence of functional interactive communication in PDOC patients, it is difficult to identify early signs of infections when compared to healthy individuals. Hence it requires timely assessment and careful observation of their behaviours.

The **Wessex Head Injury Matrix** (WHIM; Shiel et al., 2000) is a behavioural observational assessment tool commonly used for the assessment of patients in and emerging from a coma and patients in the PDOC. While recording vital signs such as heart rate and temperature is a helpful method to monitor physiological changes, the question asked in this study is whether an otherwise unexplained reduction in WHIM total score is useful in providing information which could detect early signs of infection. If so, could this improve PDOC outcomes and reduce health care costs for this population. The association between infection and worst cognitive outcome is well established for acquired brain injury (Rocco et al 2007 and Stott et al 2009) and dementia patients (Dufour et al 2015); however, to date no investigation has been conducted in patients with PDOC. Hence this study aims to add further knowledge to the existing body of literature.

Aim

To determine if a decline in WHIM score indicates the onset of an infection

Objectives

- To identify whether total WHIM scores decrease prior to a patient with PDOC acquiring an infection and to ascertain if after infection patients return to previous levels of functioning/baseline?
- To establish whether there are differences between VS & MCS and TBI & NTBI and UTI & other infection with respect to changes in total WHIM scores.

Method

Study Design

Both a retrospective and a prospective approach was used to examine whether the results of regular WHIM assessments provide an indicator to identify early signs of infections in PDOC patients.

In the retrospective study, records of all patients admitted with a diagnosis of PDOC between April 2015 and February 2017 were examined. In the prospective study, patients admitted from March 2017 to October 2017 were observed. WHIM data were used to identify cognitive behaviours. Documented infection was confirmed according to the following criteria:

- Positive culture of body fluids, tissue sample or indwelling catheters by recognized pathogenic microorganisms
- Lung examination

All patients were uniformly treated as per the practice protocol. Inclusion and exclusion criteria were the same for both retrospective and prospective studies.

Inclusion criteria

The inclusion criteria's were:

- Patients with traumatic brain injury (TBI)/non-traumatic brain injury (NTBI) (18 years and older) who were in VS/MCS 12 weeks or more after their acquired brain injury were recruited.
- Prior to the baseline assessment, patients had to have been free of infection for at least 1 week.

Exclusion criteria

PDOC of degenerative aetiology, past medical history of intellectual disability or organic mental health condition, any patient outside of diagnostic (PDOC) criteria and patients who have emerged from PDOC or patients diagnosed with locked in syndrome.

Ethical Approval

The study was approved by the local ethics committee and the Research Ethics Committee at NUI Galway. Each patient's next of kin signed an informed consent form. Data were stored in accordance with Caldicott Principles.

Study Procedure

- Retrospective: A longitudinal observational study (serial assessments of WHIM)

A pro forma was used to collect data from the case records of patients included in the study. This included demographic data, aetiology, neuroimaging/neurosurgical records, baseline WHIM score (an initial behavioural observation record), total WHIM scores (pre, during and post infection period), medication changes, infection details, any acute hospital admission entries, nursing records (vital signs), chest examination records and medication record sheet. WHIM data were analysed on a single subject basis initially using descriptive statistics and visual inspection. Changes in WHIM scores i.e. increased or decreased total WHIM scores were further evaluated to identify a possible underlying precursor such as an alteration in medication and their side effects, dietary changes, infection, sleep patterns and so forth. Changes in WHIM scores due to the infection were further studied in two groups (TBI/NTBI) to evaluate any difference between these two aetiologies.

- Prospective Study:

Patients' levels of consciousness and awareness were assessed using the RCP guidelines on PDOC (2013). The WHIM assessments were conducted by "blind" assessors who were working within the occupational therapy and neuropsychology department of the

participating hospital. As part of the assessment, varied sensory stimuli (visual, auditory, olfactory, tactile, gustatory) were provided to elicit responses from the patients and observed behaviours were documented on WHIM behavioural observational sheets. During in-patient rehabilitation each patient was screened for indications of consciousness.

Criteria for this included: (1) a behavioural manifestation of sense of self or an environment, (2) functional use of an object (3) functional interactive communication or (4) consistent choice making. During in-patient rehabilitation, each patient was evaluated on the WHIM at least 10 times over a 3 week period. In addition, all patients were monitored daily by rehabilitation assistants who documented vital signs to record physiological changes.

Baseline assessment was documented as the mean of 3 WHIM assessments carried out over different times of the day. After baseline testing, patients' cognitive behaviours were assessed for a maximum of 12 weeks using the WHIM. Weekly follow-up data, consisting of WHIM scores (at least 2-3 per week); current medications and medical complications were noted during the study period.

If behavioural changes were observed, patients were further evaluated for any changes in their sleep-wake pattern, medications alteration/sedation, medical complications, nutrition, hydration, daily schedules, positioning, environment, over-stimulation/fatigue etc. When negative change on the WHIM scores were observed these behavioural changes were reported on the same day to the relevant professionals e.g. in-house physician, nurse in-charge to do urine analysis and physio in-charge for chest auscultation and for further interventions. Patients were re-assessed on WHIM to evaluate the fluctuation and recovery of their cognition over the infection period and after the completion of an antibiotic course (if relevant). Each WHIM assessment took 20 -30 minutes to perform.

Other Interventions

Neuro-rehabilitation (multi-disciplinary therapeutic interventions, suitable medications and nursing care)

Outcome measure to assess cognition

The Wessex Head Injury Matrix (WHIM) is a 62-item hierarchical scale, which provides a sequential framework of observation covering an individual's level of responsiveness and interaction with their environment. Behaviours may occur either spontaneously or in response to stimulation. The WHIM was designed to be used by different members of the multidisciplinary team; it was developed to monitor changes from coma through to emergence from post-traumatic amnesia in patients with traumatic brain injury. It is shown to be valid and reliable in this context, (Shiel et al 2000 and Wilson et al 2009) but it also has applicability in other causes of PDOC (RCP 2013).

Data Collection

- Retrospective

Retrospective data were collected from 33 participants who were inpatients between April 2015 and Feb 2017. Of these, twelve PDOC patients were excluded from the retrospective

study due to degenerative conditions, past history of mental health illness, insufficient WHIM data and reduced WHIM scores due to reasons other than infection. In total, retrospective data were included from twenty-one PDOC patients (nine TBI and twelve NTBI). Positive cultures of respiratory secretions were present in ten patients (48% of total participants) in nine patients (43 % of total participants) infection was recorded to be urinary tract infection and in two patients other infections were documented.

- Prospective

In total, prospective data were collected from 22 PDOC patients (11 TBI and 11 NTBI) between March 2017 and Oct 2017. A positive culture of respiratory secretions was present in 11 patients (50% of total participants) and in 10 patients (49% of total participants) infection was recorded to be a urinary tract infection and in one patient another (C-diff) infection was documented.

Statistical analysis

Statistics were calculated using SPSS software. WHIM data were analysed to identify any changes in behavioural assessment measures, to determine the factors affecting consciousness and the effects of secondary complications on the level of consciousness. Data were analysed on a single subject basis initially using descriptive statistics and visual inspection. Non parametric analysis was used to examine data for associations between reduced or absent behaviours prior to diagnosis of infection e.g. a Mann-Whitney test was used to compare the differences between two independent groups (TBI vs NTBI; VS vs MCS) as the dependent variable was not normally distributed for the retrospective study group. A one sample t-test was used to analyse group (TBI vs NTBI) to determine infections and WHIM behavioural representation. A one sample t-test was used for prospective data as the dependent variable (TBI: 11 vs NTBI: 11) was normally distributed. A non-parametric Kendall's tau-b test was used to analyse co-relationship with age and gender due to a relatively large Cook's distance indicating an outlier and due to skew in difference scores in female groups and low number of females in the study. Fisher's exact test was used to examine whether the changes in total WHIM score in PDOC patients were independent of or associated with an infection. Descriptive statistics were used to allow simpler interpretation of the WHIM data e.g. graphical description (graph and table).

Results

Characteristics of the population

Twenty one PDOC patients (16 male and 5 female) were included in the final retrospective analysis. The patients ranged in age from 20 to 73 years (TBI: 20 to 59 years and NTBI: 35 to 73 years) with a mean age of 47 years. Nine patients had a TBI and 12 had a non-traumatic aetiology. All (i.e. twenty one patients) had a percutaneous endoscopic gastrostomy (PEG) for enteral nutrition, eight had a tracheostomy for breathing, three had an indwelling catheter and 11 had a cranioplasty. Amongst the 11 patients who had cranioplasty, four patients had cranioplasty during the current study period. The mean length of time since injury was approximately four years (3.95) for the whole group (range 2 to 7 years), 3.6 years for the TBI group (range 2 to 6 years) and 4.16 years for the NTBI group

(range 2 to 7 years). Seven patients had UTI and 12 patients had a respiratory infection. Two MCS patients, (one with NTBI and the other with TBI) had infection at a post-operative site (ventricular peritoneal (VP) shunt).

In the follow up (prospective) study, 22 PDOC patients (11 TBI AND 11 NTBI) were included. The majority of TBI patients were in MCS (n=9). Their ages varied from 21 to 73 years (TBI: 21 to 67 and NTBI 29 to 73). Of a total of 11 NTBI, six patients were in VS and five in MCS. Of the 11 NTBI patients, respiratory infections were noted in seven, UTI in three and one patient's medical record recorded c-diff. Of the 11 TBI patients, seven had a UTI and the rest were reported to have a respiratory infection.

Association between baseline total WHIM score and total WHIM score prior to a patient acquiring an infection

Cognitive changes were recorded using the WHIM. The results of the retrospective study indicated that WHIM total score decreased due to the infections in seventeen (80%) of the 21 infection cases ($p<0.001$). When data for the TBI and the NTBI patients are examined separately, all TBI patients ($p=0.008$) but only eight ($p=0.034$) of the twelve NTBI patients showed decreased behaviours. Interestingly the majority of the patients who showed changes were in MCS (100%) and only 3 patients were in VS (42%).

The results of the prospective study indicated that WHIM total score decreased due to the infections in fifteen (68% $p=0.001$) of the 22 infection cases. When data for the TBI and the NTBI patients are examined separately, seven of the eleven TBI patients (64%) and eight of eleven NTBI patients (73%) showed higher baseline scores when compared to pre-infection. That is to say there were no differences in proportions of people showing increase/no change/decrease total WHIM scores from baseline to pre-infection noted between TBI and NTBI (Fisher $p=1.00$). 86% of MCS and only 38% of VS patients showed a decrease in total WHIM score at pre-infection level (Fisher exact $p=0.011$).

This emphasises that similar results were obtained for both retrospective and prospective studies i.e. MCS patients showed a bigger proportion of change in total WHIM scores at baseline to pre-infection level when compared to VS.

Association between baseline and post-infection total WHIM score

Ten of twenty one patients from the retrospective study returned to previous levels of functioning after an infection episode. Of these six had TBI and four had NTBI. Two TBI and one NTBI patients' total WHIM scores remained below the baseline level after recovery from the infection. Both TBI patients' cognitive levels dropped from MCS to VS where they showed reflexive behavior only. The infection (1 TBI and 1 NTBI) was recorded at post-operative site (Ventricular Peritoneal shunt infection and infected cranioplasty). The TBI patient with VP shunt infection died while NTBI patient with infection at cranioplasty started to slowly regain some of the previous level of functioning.

Twelve of twenty-two patients from the prospective study continued to show cognitive improvement after recovery from infections. 23% of the total population showed higher total WHIM score at post infection when compared to baseline whereas 36% of total population

showed no change and amongst 41% patients total WHIM score remains low at post infection (TBI vs NTBI $P=1.00$ and MCS vs VS $p=0.27$).

This highlights that similar results were obtained from both retrospective and prospective studies i.e. no differences were noticed in proportions of people showing increase/no change/decrease total WHIM scores between baseline and post-infection for TBI and NTBI.

Association between pre and post-infection total WHIM score

Post infection total WHIM scores were higher than pre-infection scores in the retrospective sample ($p=0.001$). The largest difference was between pre and post infection scores for MCS patients ($p=0.004$); however there were no differences between TBI vs NTBI with both showing higher post infection scores (TBI $p=0.020$ and NTBI $p=0.028$). Similarly no differences were recorded between groups for different types of infection or between males and females. 55% of patients from the prospective study continued to show cognitive improvement after recovery from infections. Similar to the results in the retrospective study, the largest differences were noticed between pre and post infection scores for MCS patients (64%); however no such differences were noticed amongst TBI vs NTBI ($p=0.73$) although compared to males (69%) who tended to show higher post infection scores female patients (83%) tended to show no change (Fisher exact $p=0.013$).

Discussion

This study set out to examine whether a decline in WHIM scores indicates the presence of an infection in patients in PDOC. The authors found a general relationship between a drop in total WHIM scores and infection. The MCS patients showed a bigger proportion of change compared to the patients with VS between their baseline score and the scores taken at the pre-infection stage in both the retrospective (100%) and prospective (85%) studies. The association between infection and worse cognitive outcome is well established both for acquired brain injury (Rocco et al 2007 and Stott et al 2009) and dementia patients (Dufour et al 2015) however, to date no investigation has been conducted in patients with PDOC. Hence this study adds further knowledge to the existing body of literature.

Infection is a common cause of morbidity in the general medical population, but patients in PDOC are particularly vulnerable. In the absence of functional interactive communication in PDOC patients, it is important to identify early signs of infections. The WHIM was chosen for this current study as it measures subtle changes in patient's cognitive behaviour over time (RCP guidelines on PDOC 2013). Wilson et al (2009) in their study showed that a serial record of WHIM scores can be used to monitor the consistency of responses, as well as trends towards change over time.

A review by the US Task Force (Seel et al 2010) identified 13 cognitive assessments for PDOC with minor/moderate reservations including WHIM, JFK CRS-R and SMART. A UK survey demonstrated that the WHIM is the most commonly used tool in the UK, followed by the SMART and then the CRS-R (RCP guidelines on PDOC 2013). The WHIM covers a different range of responses from the SMART and CRS-R. Its ceiling extends beyond that of the CRS-R or SMART to track patients until they emerge from post-traumatic amnesia. The

WHIM is relatively easy to employ in neurorehabilitation settings, requires minimal staff training and is less time-consuming to administer thereby facilitating regular or routine serial assessments (RCP guidelines on PDOC 2013) when compared to Sensory Modality assessment and Rehabilitation Techniques (SMART; Gill-Thwaites & Munday, 1999). While SMART undoubtedly provides a more robust assessment of patients who are queried to be in VS it also requires extensive specialist training and is not widely available. Similar to SMART, the JFK Coma Recovery Scale-Revised (JFK CRS-R; Giacino, Kalmar and Whyte, 2004) covers a broadly similar range of responses; however use of the JFK CRS-R has not been widely documented in UK settings (Wilson et al 2009).

The authors examined the patterns of change in total WHIM scores recorded serially over time to determine whether the baseline data would change prior to patient obtaining an infection. Fifteen PDOC patients from the prospective study showed a drop in WHIM scores prior to developing an infection. On further analysis, the rates of change in total WHIM scores increased progressively across twelve PDOC patients at post-infection stage. This emphasises that the serial application of WHIM is an important indicator to identify early signs of infection.

The results of the retrospective study indicated that WHIM total scores decreased due to infections in 80% of patients with infection; similarly the prospective study showed that WHIM total score decreased due to the infections in 68% of patients with infections. The results of the study confirm that at pre-infection stage some patients demonstrated decreased wakefulness, lethargy and decreased alertness. Others presented with increased agitation and vocalisation. All patients presented with raised temperature and with an increased pulse rate compared to their baseline. Patients with respiratory infection showed increased respiratory rates but decreased oxygen saturation. With regards to alertness, patients with respiratory infections were observed and documented to be sleepier while patients with urinary infection were more restless (WHIM no. 11). This increased restlessness and agitation prior to urination could be due to pain as a consequence of the UTI.

The RCP guidelines (2013) suggest that the cause of injury is an important factor for outcome of patients in PDOC and that patients with NTBI have a shorter window of recovery compared to patients with TBI. In four of the reported infections (out of twenty one from retrospective study) there was no change in total WHIM scores. These patients all had a non-traumatic aetiology. An explanation for this may be that these patients were in VS and their total WHIM score was already too low to show any meaningful changes in their WHIM behaviour. Similar results were noticed for the prospective study where no changes noticed in total WHIM scores for six patients. Of those six patients five were in VS.

Conclusion

An unexplained reduced WHIM score appears to be a predictor of underlying infections. The MCS patients showed a bigger proportion of change between their baseline score and the scores taken at the pre-infection stage in both the retrospective and prospective studies compared to the patients with VS. Thus the findings of the study suggest the importance of serial/regular WHIM assessments throughout the period of recovery not only to measure

cognitive changes but also to highlight underlying physical changes such as infections that will impact on rehabilitation and recovery. Timely understanding of the risk of infection among brain injury patients could minimise infection related longer hospital stays and adverse outcomes.

Acknowledgement

We would like to thank Gerhard Florschütz for his support.

References

- Aslanyan S, Weir CJ, Johnston SC, Lees KR. Poststroke Neurological Improvement Within 7 Days Is Associated With Subsequent Deterioration. *Stroke*. 2004; 35:2165–2170. [PubMed: 15243144]
- Boehme AK, Kumar AD, Dorsey AM, Siegler JE, Aswani MS, Lyerly MJ, Monlezun DJ, George AJ, Albright KC, Beasley TM, Martin-Schild S. Infections present on admission compared with hospital-acquired infections in acute ischemic stroke patients. *J Stroke Cerebrovasc Dis*. 2013; 22:e582–e589. [PubMed: 23954599]
- Colbert JF, Traystman RJ, Poisson SN, Herson PS, Ginde AA. Sex related differences in the risk of hospital-acquired sepsis and pneumonia post-acute ischaemic stroke. *Journal of Stroke and Cerebrovascular Diseases*. 2016; 25(10):2399–2404. [PubMed: 27363622]
- Dufour AB, Shaffer ML, D'Agata EMC, Habtemariam D, Mitchell SL. Survival after suspected urinary tract infection in individuals with advanced dementia. *Journal of the American geriatrics society*. 2015; 63(12):2472–2477. [PubMed: 26613981]
- George AJ, Boehme AK, Siegler JE, Monlezun D, Fowler BD, Shaban A, Albright KC, Beasley TM, Martin-Schild S. Hospital-acquired infection underlies poor functional outcome in patients with prolonged length of stay. *ISRN Stroke*. 2013; 2013:5.doi: 10.1155/2013/312348
- Giacino J, Kalmar K, Whyte J. The JFK coma recovery scale-revised: measurement characteristics and diagnostic utility. *Arch Phys Med Rehabil*. 2004; 85:2020–2029. [PubMed: 15605342]
- Gill-Thwaites H, Munday R. The Sensory Modality Assessment and Rehabilitation Technique (SMART): a valid and reliable assessment for vegetative state and minimally conscious state patients. *Brain Inj*. 2004; 18:1255–69. [PubMed: 15666569]
- Loveday HP, Wilson JA, Pratt RJ, Golsorkhi M, Tingle A, Bak A, Browne J, Prieto J, Wilcox M. epic3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England. *Journal of Hospital Infection*. 2014; 86S1:S1–S70.
- National Audit Office. Reducing healthcare associated infections in hospitals in England. London: The Stationery Office; 2009. [Internet]; Available from. Sharps injuries can result in serious or life. www.nao.org.uk/publications/0809/reducing_healthcare_associated.aspx [cited 2017 Oct 1]
- NICE guidelines infection prevention and control. [cited 2017 Oct 12] 2014. [Internet]; Available from. <https://www.nice.org.uk/guidance/qs61>
- Popovic N, Stefanovic-Budimkic M, Mitrovic N, Urošević A, Milošević B, Pelemiš M, Jevtović D, Besla -Bumbaširević L, Jovanović D. The frequency of post-stroke infections and their impact on early stroke outcome. *J Stroke Cerebrovasc Dis*. 2013; 22:424–429. [PubMed: 23540255]
- Quality improvement guide. [Cited 2017 March 22] Prevention and control of healthcare associated infections. Costing report. Implementing NICE guidance. 2011. [Internet]; Available from. <https://www.nice.org.uk/guidance/ph36/resources/costing-report-68913469>
- Rocco A, Pasquini M, Cecconi E, Sirimarco G, Ricciardi MC, Vicenzini E, Altieri M, Di Piero V, Lenzi GL. Monitoring after the acute stage of stroke: a prospective study. *Stroke*. 2007; 38:1225–1228. [PubMed: 17322080]
- Royal College of Physicians. Prolonged disorder of consciousness. London: 2013. [Internet]; Available from: <https://www.rcplondon.ac.uk/guidelines-policy/prolonged-disorders-consciousness-national-clinical-guidelines> [cited 2017 Jan 15]
- Seel RT, Sherer M, Whyte J, Katz DI, Giacino JT, Rosenbaum AM, Hammond FM, Kalmar K, Pape TL, Zafonte R, Biester RC, et al. Assessment scales for disorders of consciousness: evidence-

- based recommendations for clinical practice and research. *Arch Phys Med Rehabil.* 2010; 91:1795–1813. [PubMed: 21112421]
- Shiel A, Horn SA, Wilson BA, Watson MJ, Campbell MJ, McLellan DL. The Wessex Head Injury Matrix (WHIM) main scale: a preliminary report on a scale to assess and monitor patient recovery after severe head injury. *Clin Rehabil.* 2000; 14:408–416. [PubMed: 10945425]
- Stott DJ, Falconer A, Miller H, Tilston JC, Langhorne P. Urinary tract infection after stroke. *Qjm.* 2009; 102:243–249. [PubMed: 19233882]
- Tate JA, Snitz BE, Alvarez KA, Nahin RL, Weissfeld LA, Lopez O, Angus DC, Shah F, Ives DG, Fitzpatrick AL, Williamson JD, et al. Infection Hospitalization Increases Risk of Dementia in the elderly. *Critical Care Medicine.* 2014; 42(5):1037–1046. [PubMed: 24368344]
- Weimar C, Ziegler A, König I, Diener HC. Predicting functional outcome and survival after acute ischemic stroke. *J Neurol.* 2002; 249(7):888–895. [PubMed: 12140674]
- Wilson FC, Elder V, McCrudden E, Caldwell S. Analysis of Wessex Head Injury Matrix (WHIM) scores in consecutive vegetative and minimally conscious state patients. *Neuropsychological Rehabilitation.* 2009; 19(5):754–760. [PubMed: 19378215]

Figure 1. A comparison of baseline, pre-infection and post-infection total WHIM scores for TBI and NTBI retrospective study patients.

Figure 2. A comparison of baseline, pre-infection and post-infection total WHIM scores for TBI and NTBI prospective study patients.

Table 1
characteristics of the study population.

Etiology	Gender	Age	PDOC	Type of infection	Total WHIM score Prospective data		
					Baseline	Pre infection	Post infection
TBI							
1TBI	M	34	MCS	UTI	19	18	18
2TBI	M	41	MCS	UTI	21	23	21
3TBI	M	21	MCS	Chest	17	15	21
4TBI	F	67	MCS	UTI	10	10	10
5TBI	M	41	MCS	UTI	20	15	18
6TBI	M	41	MCS	UTI	23	16	21
7TBI	M	34	MCS	Chest	15	12	13
8TBI	M	25	MCS	Chest	15	12	17
9TBI	M	25	MCS	Chest	12	10	9
10TBI	F	47	VS	UTI	5	5	5
11TBI	F	47	VS	UTI	4	4	4
NTBI							
1NTBI	F	41	MCS	Chest	19	13	19
2NTBI	M	55	MCS	Chest	21	15	22
3NTBI	M	43	MCS	UTI	16	13	18
4NTBI	M	71	MCS	Chest	10	6	9
5NTBI	M	29	MCS	c-diff	13	12	10
6NTBI	M	44	VS	Chest	5	3	4
7NTBI	M	34	VS	UTI	8	6	9
8NTBI	M	73	VS	Chest	6	2	5
9NTBI	F	68	VS	Chest	5	5	5
10NTBI	F	35	VS	UTI	6	6	6
11NTBI	M	73	VS	Chest	5	5	5

Patients	Gender	Age	PDOC	Type of infection	Total WHIM score Retrospective data		
					Baseline	Pre infection	Post infection
TBI							
1TBI	M	25	MCS	Respiratory	12	8	14
2TBI	M	41	MCS	Respiratory	21	16	23
3TBI	M	20	MCS	UTI	20	16	21
4TBI	M	34	MCS	Respiratory	22	13	21
5TBI	M	20	MCS	Respiratory	16	13	12
6TBI	M	20	MCS	UTI	20	15	21
7TBI	M	54	MCS	UTI	19	11	17
8TBI	M	52	MCS	VP shunt & CNS infection. Ventriculitis after Cranioplasty	20	4	4

Patients	Gender	Age	PDOC	Type of infection	Total WHIM score Retrospective data		
					Baseline	Pre infection	Post infection
9-TBI	M	59	MCS	Respiratory Admission to A & E	13	5	6
NTBI							
1-NTBI	M	41	MCS	Respiratory	14	9	15
2-NTBI	F	41	MCS	VP shunt and cranioplasty infection	25	5	14
3-NTBI	M	55	MCS	Respiratory	19	10	22
4-NTBI	M	70	MCS	Respiratory	15	11	14
5-NTBI	M	71	MCS	UTI	10	6	10
6-NTBI	M	61	VS	UTI	8	8	8
7-NTBI	M	43	VS	UTI	6	6	6
8-NTBI	F	68	VS	Respiratory	8	6	7
9-NTBI	F	68	VS	Respiratory	6	6	6
10-NTBI	F	46	VS	Respiratory	6	5	5
11-NTBI	F	35	VS	UTI	7	6	6
12-NTBI	M	73	VS	Respiratory	6	6	6

TBI: Traumatic brain injury **NTBI:** Non-traumatic brain injury **UTI:** Urinary Tract Infection **PDOC:** prolonged disorders of consciousness **MCS:** Minimally conscious state **VS:** Vegetative state