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# The impact of nutritional status on the outcome of Indian patients undergoing neurosurgical shunt surgery†

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Undernutrition is common in surgical patients, is frequently unrecognised and is strongly associated with adverse outcomes such as high rates of complications and mortality, worsening functional status and prolonged hospitalisation. Owing to the associated infection and symptoms such as repeated vomiting, a high prevalence of undernutrition is expected in hydrocephalus patients, which may contribute to their poor surgical outcomes. The aim of this study was to evaluate the influence of preoperative nutritional status on the outcome of Indian patients with hydrocephalus undergoing neurosurgical shunt surgery. One hundred and twenty-four consecutive patients undergoing scheduled hydrocephalus shunt surgery were studied prospectively. All patients underwent nutritional screening according to different parameters prior to surgery. The patients were classified into normally nourished and undernourished groups. The undernourished group was further subdivided into moderately and severely undernourished. The surgical outcome was compared between these groups. A high prevalence (53 %) of undernutrition was observed in these patients. Postoperative complications such as shunt infection ($P=0{\cdot}0023$), shunt revision ($P=0{\cdot}0074$) and mortality ($P=0{\cdot}0003$) were significantly more common in undernourished patients compared with normally nourished patients. Serum albumin emerged as the most significant independent predictor of postoperative mortality. The present study demonstrated a high prevalence of undernutrition in hydrocephalus patients in India and its adverse influence on the outcome of shunt surgery. Early preoperative nutritional status screening and its optimisation may decrease the morbidity and mortality of shunt surgery for hydrocephalus.

**Nutritional status: Hydrocephalus: Neurosurgical shunt surgery**

The influence of nutritional status on the course of an illness was already known to Hippocrates when he stated that well-fed patients would recover more quickly[1]. Since then, numerous studies have widely acknowledged the deleterious effects of impaired nutritional status on clinical outcome[2–4] and hospital costs[5]. Undernutrition, however continues to be a significant problem in surgical patients, with up to 40 % of patients being undernourished on admission to hospital, and about 78 % of the undernourished patients who stay longer in hospital losing further weight[6–8].

This deterioration of nutritional status in the patient undergoing surgery may result in reduced systemic immunity, an exaggerated stress response, organ system dysfunction, poor wound healing and delayed functional recovery[7,9–14]. Therefore, careful preoperative nutritional assessment followed by the initiation of appropriate nutritional therapies has been proposed to improve outcomes[12]. Hydrocephalus is a clinical condition marked by the excessive accumulation of cerebrospinal fluid within the cerebral ventricles. It is more frequent in children and results from congenital or acquired disease processes including developmental anomalies, neoplasms and traumatic or inflammatory conditions[15].

Hydrocephalus is a common neurosurgical entity, especially in the developing countries where tubercular meningitis is prevalent[16]. Regardless of aetiology, shunt insertion (venticulo-peritoneal[17] or lumbo-peritoneal[16]) is still the most common form of treatment for hydrocephalus. Despite improved shunt valve technology and surgical techniques, the treatment of hydrocephalus is still, however, associated with unsatisfactory outcomes[17,18].

Several risk factors have been identified for poor outcome, including demographic variables, aetiology, associated pathology and timing of the shunt[18–20]. Because of associated vomiting, altered sensorium and chronic infections such as tuberculosis, a large number of these patients are expected to be undernourished[21]. Surprisingly, the effect of preoperative nutritional status on the outcome of patients has not been reported in the literature. Indeed, the relationship between poor nutritional status and subsequent postoperative morbidity and mortality is well recognised in the surgical literature[13,14,22].

This study aims to determine the prevalence of undernutrition and its influence on outcome and hospital stay in hydrocephalus patients undergoing shunt surgery in India. In addition, we also sought to determine the nutrition parameter

**Abbreviations:** GCS, Glasgow coma scale; ICP, intracranial pressure; LP shunt, lumbo-peritoneal shunt; MAC, mid-arm circumference; MAMC, mid-arm muscle circumference; SFT, skin fold thickness; SA, serum albumin; TBM, tubercular meningitis; VP shunt, ventriculo-peritoneal shunt.

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that has the most significant predictive value of poor outcome, especially mortality after shunt surgery.

## Subjects and methods

### *Study population*

This prospective study was performed on 124 patients with hydrocephalus treated with shunt surgery at the department of neurosurgery between November 2001 and December 2003. Patients undergoing emergency shunt procedures were excluded from the study. The study was approved by the Central ethical committee, NSCB Medical College and Hospital, Jabalpur, India. Informed consent was obtained from parents/legal representatives of the patients.

Patients from all age groups were included in the study. The paediatric age group (<15 years) formed the majority (87 %) of the patients. The median age of the studied population was 3 years, and the male-to-female ratio 1.8:1. The demographic details of the subjects and the aetiologies of hydrocephalus are summarised in Table 1. Tubercular meningitis was the most common cause in 53 % of cases. All the shunt surgery was carried out by a senior neurosurgeon (Y.R.Y.). Ventriculo-peritoneal shunting was performed in 65 % (*n* 81) of patients, and lumbo-peritoneal shunting in 35 % (*n* 43). Intravenous ceftriaxone was administered to all patients postoperatively for 7 d, and antitubercular treatment and steroids were given to selected patients based on their aetiology. Shunting in pyogenic meningitis was carried out when active infection was controlled by antibiotics. Raised intracranial pressure in these patients was controlled by external ventricular/lumbar drainage.

### *Nutritional assessment*

A detailed preoperative nutritional assessment was carried out on the 3 d prior to surgery. This included a thorough history (dietary and drug history, weight loss, etc.), physical examination, anthropometric measurements and laboratory investigations as defined by the American Society for Parenteral and Enteral Nutrition (1995)[23].

**Table 1.** Demographic and clinical characteristics of the study population

| | Patients (*n* 124) |
|---|---|
| Demographics | |
| Age (years) (median and range) | 3 (4 months to 68 years) |
| Sex (male:female) | 1·8:1 |
| Aetiology of hydrocephalus | |
| Tubercular meningitis | 66 (53 %) |
| Bacterial meningitis | 22 (18 %) |
| Associated with meningomyelocele | 4 (4 %) |
| Associated with tumour | 6 (5 %) |
| Congenital hydrocephalus | 22 (18 %) |
| Spinal *dysraphism* | 2 (1 %) |
| Post-head injury cerebrospinal fluid leak | 2 (1 %) |
| Clinical | |
| Glasgow Coma Scale | |
| 3–8 | 36 (29 %) |
| 9–12 | 48 (39 %) |
| 13–15 | 40 (32 %) |
| Shunt surgery | |
| Ventriculo-peritoneal shunt | 81 (65 %) |
| Lumbo-peritoneal shunt | 43 (35 %) |

### *Anthropometry*

The anthropometric data collected included height, weight, mid-arm circumference and skinfold thickness. The mid-arm circumference was measured at the mid-point between the acromion and the olecranon. The skinfold thickness at the triceps was measured using a Harpenden caliper (Sigma Instrument Company, Mumbai, India) to the nearest 0·2 mm. Measurements were taken on the non-dominant arm with the subject standing in a relaxed position. The measurements were performed in the lying position in neonates unable to stand (*n* 36). The measurements were repeated three times, and the mean score was recorded. The same investigator performed all the anthropometric measurements.

Assessment of muscle mass was made by calculating the mid-upper arm muscle circumference using the formula (Jelliffe & Jelliffe, 1969):

$$\text{MUAMC (cm)} = \text{MUAC} - \text{pTSF},$$

where MUAMC is mid-upper arm muscle circumference, MUAC is mid-upper-arm circumference and pTSF is p x triceps skinfold thickness. BMI was calculated from height and weight[24]. The weight and height for age and gender was used in the paediatric population, and BMI in the adult population.

### *Laboratory measurements*

Laboratory data were measured by established standard laboratory methods on the same day of anthropometric evaluation. These included Hb, total protein, serum albumin, complete blood picture, cerebrospinal study, clotting studies and serum electrolytes. Due to resource limitations, some nutritional indicators, such as serum transferrin, immunoglobulin, prealbumin and retinol-binding protein, could not be assessed in every patient. Based on these parameters, the patients were classified into normally nourished and undernourished groups. The undernourished group was further subdivided into moderately malnourished and severely malnourished (Table 2). Weight-for-age values were compared with age- and sex-standardised data, provided by National Centre for Health Statistics with WHO criteria (SD classification)[25]. Tanner's standards were taken for triceps skinfold thickness and mid-arm muscle circumference, and were categorised in accordance with international standards (Jelliffe, 1996).

### *Outcomes*

The outcome of surgery was compared between these groups in terms of postoperative complications (shunt infection, shunt block), reoperation (shunt revision), mortality (until 1 month postoperatively) and duration of hospitalisation. The follow-up period ranged from 3 months to 2 years 3 months, with a mean of 16 months. Shunt infection was defined as isolation of organisms from the cerebrospinal fluid or shunt tube; the

**Table 2.** Parameters of grading of nutritional status

| Level of nutrition | Weight for age | BMI (kg/m$^2$) | Mid-arm muscle circumference (cm) | Skinfold thickness (mm) |
|---|---|---|---|---|
| Normally nourished | Expected weight for age − 2 SD | > 18·5 | > 95th percentile | > 95th percentile |
| Moderately undernourished | 2–3 SD | 6–18·4 | < 10th percentile | < 10th percentile |
| Severely undernourished | > 3 SD | < 15·9 | < 5th percentile | < 5th percentile |

microscopic picture of the cerebrospinal fluid revealed increased cell counts or significant signs of inflammation along the tract[26]. Superficial wound infection was defined as minor infections such as stitch abscess, which did not fall into the category of shunt infection. These infections do not require removal of the shunt. Shunt block was diagnosed by computed tomography scan, when the patient did not improve or deteriorated, as ventriculomegaly with evidence of increased intracerebral pressure[26].

### *Statistical analysis*

Statistical analysis between the nutritional status groups for each outcome was performed by means of the $\chi^2$ test for categorical variables (shunt infection, shunt revision, mortality) and an unpaired student's *t* test for continuous variables (hospital stay). In addition, mortality and nutritional status were compared by odds ratio, univariate and multivariate analysis. The most significant, independent predictor of postoperative mortality was assessed by ANOVA. A *P* value of less than 0·05 was considered to be statistically significant. All statistical analyses were performed using Graphpad Prism (GraphPad Software, San Diego, CA, USA) and SPSS 13.0 for windows (SPSS Inc., Chicago, IL, USA) software.

## Results

### *Population characteristics*

Of the 124 patients, sixty-three (46·6 %) fulfilled the criteria for being normally nourished by all parameters of nutrition. The remaining sixty-one (53·4 %) were undernourished by at least one parameter. When considering all the parameters separately (weight for age or BMI, mid-arm circumference, skinfold thickness), this incidence was 50 %, 42 % and 48 %, respectively (Table 3).

### *Predictive value of different parameters*

The odds ratio was calculated to show the associations between predictive variables and outcome variables (adverse outcome). Based on the results, serum albumin emerged as the most significant independent predictor of postoperative complications in patients undergoing hydrocephalus shunt surgery in our study population. Therefore, for simplicity, the results in the next section are mentioned in terms of serum albumin; other parameters are summarised in the Table 4.

### *Outcome*

Recovery was uneventful in eighty-four (68 %) patients (without any postoperative complication). Twelve patients (10 %) had a superficial wound infection, which was treated by repeated sterile dressings and antibiotics. The type of surgery did not have any influence on the outcome.

### *Shunt infection*

Shunt infection was encountered in twenty-one (16 %) cases. These shunts were removed, and appropriate antibiotics were administered according to culture reports. Half of these patients succumbed due to septicaemia, and the remaining half underwent a revision of their shunt. The undernourished patients had a significantly higher incidence of shunt infection compared with normally nourished patients (incidence of shunt infection: normally nourished, 7·4 %; undernourished, 28 %; $\chi^2 = 9{\cdot}297$, $P = 0{\cdot}0023$). In the undernourished group, the severely undernourished patients were more prone to shunt infection than their moderately undernourished counterparts (Table 4).

### *Shunt block*

Shunt block was encountered in thirteen (10 %) cases. Shunt blockage was more common in undernourished 14 % (8/60) cases compared with normally nourished cases; this difference did not, however, prove to be statistically significant (incidence of shunt blockage: normally nourished, 7·4 %; undernourished, 14 %; $\chi^2 = 1{\cdot}418$, $P = 0{\cdot}2338$).

### *Shunt revision*

Shunt revision was performed in 13 % cases (16/124). The peritoneal end was reinserted in 33 % of these cases, and the whole shunt was removed in 26 % of cases. One shunt revision was carried out in ten patients, whereas two and three revisions were performed in two and four patients,

**Table 3.** Incidence of undernutrition in shunt patients based on different parameters (*n* 124)

| Level of nutrition | Weight for age + BMI | Mid-arm muscle circumference | Serum albumin | Skinfold thickness |
|---|---|---|---|---|
| Normally nourished | 62 (50 %) | 72 (58 %) | 67 (54 %) | 64 (52 %) |
| Moderately undernourished | 54 (43 %) | 35 (28 %) | 45 (36 %) | 48 (38 %) |
| Severely undernourished | 8 (7 %) | 17 (14 %) | 12 (10 %) | 12 (10 %) |

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**Table 4.** Outcome and adverse events in each group according to the different parameters of nutritional assessment

| Parameter | Nourished/Undernourished | Shunt infection | Shunt block | Shunt revision | Mortality |
|---|---|---|---|---|---|
| Weight for age or BMI | Normally (*n* 62) | 9 (14·5 %) | 6 (9·7 %) | 11 (17·7 %) | 5 (8·1 %) |
| | Moderate (*n* 54) | 10 (18·5 %) | 5 (9·2 %) | 13 (24·0 %) | 11 (20·3 %) |
| | Severe (*n* 8) | 2 (25 %) | 2 (25 %) | 2 (25 %) | 3 (37·5 %) |
| Mid-arm muscle Circumference | Normally (*n* 72) | 7 (9·7 %) | 5 (6·9 %) | 12 (16 %) | 7 (9·7 %) |
| | Moderate (*n* 35) | 8 (22·8 %) | 6 (17 %) | 9 (25·7 %) | 7 (20 %) |
| | Severe (*n* 17) | 6 (35 %) | 2 (11·7 %) | 5 (29 %) | 5 (29 %) |
| Skinfold thickness | Normally (*n* 64) | 8 (12 %) | 6 (9·3 %) | 10 (15 %) | 5 (7·4 %) |
| | Moderate (*n* 48) | 9 (18·7 %) | 5 (10·4 %) | 12 (25 %) | 11 (22·9 %) |
| | Severe (*n* 12) | 4 (33 %) | 2 (16·6 %) | 4 (33 %) | 3 (25 %) |
| Serum albumin | Normally (*n* 67) | 5 (7·4 %) | 5 (7·4 %) | 8 (11 %) | 3 (4·4 %) |
| | Moderate (*n* 45) | 11 (24·4 %) | 6 (13·3 %) | 14 (31·1 %) | 10 (22·2 %) |
| | Severe (*n* 12) | 5 (41·6 %) | 2 (16 %) | 4 (33 %) | 6 (50 %) |

respectively. Thus, a total of twenty-six procedures were performed in sixteen patients. The shunt revision was more frequently performed in undernourished patients compared with normally nourished patients (number of shunt revisions: normally nourished, 8/67 patients; undernourished, 18/57 patients; $\chi^2 = 7{\cdot}168$, $P = 0{\cdot}0074$).

### *Mortality rate*

The overall mortality rate was 15 % (*n* 19) in shunt patients. The mortality rate was significantly higher in undernourished compared with normally nourished patients (mortality rate: normally nourished, 4·4 %; undernourished, 28 %; $\chi^2 = 13{\cdot}21$, $P = 0{\cdot}0003$). In the undernourished group, mortality rate increased with decreasing level of nutrition. Thus, the severely undernourished patients had the highest incidence of mortality, compared with moderately undernourished patients ($\chi^2 = 18{\cdot}85$, $P < 0{\cdot}0001$). This trend was seen with all the parameters studied (Table 4).

The mortality rate among different grades of nutrition was also evaluated in the patients of the same neurological status. In the lowest Glasgow Coma Scale (GCS) score group (GCS 3–8), the mortality rate in undernourished patients was significantly higher than that in normally nourished patients belonging to same neurological status group ($\chi^2 = 8{\cdot}64$, $P < 0{\cdot}001$; Fig. 1). This trend was maintained in the other two groups (GCS 9–12, GCS 13–15), but it missed statistical significance.

### *Duration of hospitalisation*

The mean duration of hospital stay in all patients was 7 d (range 5–9 d). The hospital stay of patients who died was excluded from the analysis. The average hospital stay was seen to be longer in undernourished patients than normally nourished patients (mean number of days of hospital stay: normally nourished, 6·8 (SE 1·8); undernourished, 10·4 (SE 2·0)). The duration of hospital stay became longer with decreasing level of nutrition (moderately nourished, 8·9 (SE 2·2) d; severely undernourished 12 (SE 2·1) d). The duration of hospital stay was also compared in normally and undernourished patients of the same neurological status. It was observed that the undernourished patients stayed in the hospital for a longer period than normally nourished patients of the same GCS level.

## Discussion

To our knowledge, this is the first study to report the prevalence of undernutrition in patients with hydrocephalus and its influence on the outcome of shunt surgery. Our results suggest that approximately half (53 %) of our hydrocephalus patients undergoing shunt surgery were undernourished. The high prevalence of undernutrition in these patients may be due to the associated vomiting, altered sensorium and chronic infections such as tuberculosis[21], although this figure may be an overestimate due to the higher incidence of malnutrition in developing countries and the poor socioeconomic status of their patients. Furthermore, our series may not be truly representative, as most of our patients had an infective aetiology such as tuberculosis; these, by themselves, are frequently associated with undernutrition. Therefore, further studies with a larger number of cases and a uniform case mix are indicated to confirm this prevalence.

The majority (87 %) of patients in our study were in the paediatric age group, which reflects the high prevalence of tubercular meningitis in younger age groups in developing countries. Undernutrition in this group may have far more

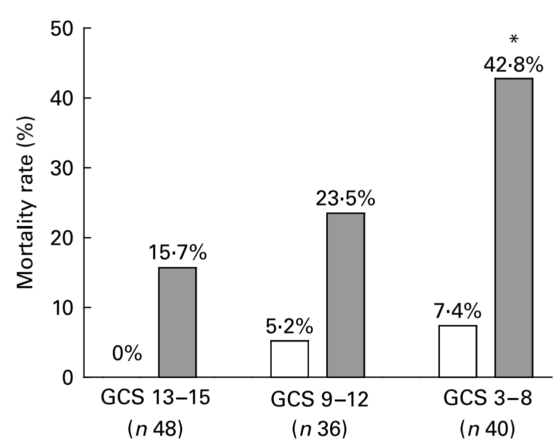


**Fig. 1.** Mortality rate in normally nourished (□) and undernourished (■) patients in different Glasgow Coma Scale (GCS) groups (based on serum albumin). *Denotes the difference was statistically significant.

implications owing to the associated biological stresses of growth and development and the rapid changes that occur during the functional maturation of organs and systems[27]. Furthermore, they have a proportionately smaller nutritional reserve compared with adults. In addition, surgery per se exaggerates the catabolic state of these nutritionally depleted patients. It is therefore mandatory to know the metabolic response of ill patients and their nutritional requirements.

Despite progress and the development of new techniques, the assessment of nutritional status still remains complicated and depends on various parameters. This fact makes nutritional assessment laborious and difficult to interpret. Although a single laboratory result may be helpful for nutritional screening, there is no single parameter that is both sensitive and specific for the diagnosis of undernutrition or a reliable predictor of poor outcome. In the present study, patients with a low serum albumin level were associated with higher complication rates and mortality.

The preponderance of postoperative complications such as shunt infection was seen in the undernourished group and was reflected in the higher shunt revision rate in that group. This incidence increased with the decreasing level of nutrition. Similarly, the mortality rate was higher among the undernourished patients compared with normally nourished patients. This trend was maintained when the normally nourished and undernourished patients of similar neurological status were compared. The results of this study clearly suggest that undernutrition has an adverse influence on the clinical outcome of hydrocephalus patients undergoing shunt surgery. This also had an impact on the duration of hospitalisation, as the undernourished patients stayed in the hospital for an extra 4 d compared with their normally nourished counterparts.

The overall outcome appeared to be poorer in patients with a low mid-arm muscle circumference and skinfold thickness compared with patients with a low mid-arm muscle circumference and normal skinfold thickness values. This difference proved to be statically significant in the shunt infection and revision rates, although it missed significance for mortality rate and hospital stay. Further studies with larger numbers of patients are needed to confirm this preliminary observation to conclude whether being undernourished per se or having a low muscle mass has a more pronounced adverse effect on outcome.

This study was the first of its kind in hydrocephalus patients, but our results are in general agreement with similar studies considering other surgical conditions, which have shown that poor nutritional status has been associated with higher rates of complications, an increased incidence of nosocomial infection, higher hospital costs, higher mortality rates and longer lengths of stay in hospital[6,9–11,14,28]. The overall cost of management for postoperative wound infections, reoperation and increased hospitalisation may be substantial compared with the costs of optimisation of nutritional status. Based on the findings of this study, it would appear that screening for undernutrition, followed by the initiation of nutritional therapies, may have a significant impact on the outcome and cost-effectiveness of shunt surgery in hydrocephalus. Therefore, a prospective study to evaluate the benefit of optimisation of nutritional status in undernourished hydrocephalus patients undergoing shunt surgery is indicated to confirm this proposal.

Although the optimisation of nutritional status appears to be beneficial, it is important to consider other aspects of hydrocephalus management, especially the timing of the shunt. It has been documented that an excessive delay ($>1$ month) in the insertion of the shunt after diagnosis apparently results in a higher chance of mental, speech and language, and possibly hearing impairment[15,19]. These damaging effects of hydrocephalus, resulting from delaying the shunt, should not outweigh the benefits gained by optimising the nutritional status of the patient. Therefore, early nutritional assessment and intervention is crucial in these patients.

To conclude, approximately half of the hydrocephalus patients undergoing shunt surgery in India are undernourished. The incidence of postoperative complications such as shunt infection, shunt revision, mortality and duration of hospitalisation was significantly higher in undernourished patients. Early preoperative nutritional assessment and optimisation of nutritional status, where appropriate, may prove beneficial in the management of hydrocephalus.

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