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Trauma Rehabilitation of Traumatic Brain Injury: A Physical Therapy Perspective in the Management of Muscular Complications, Heterotopic Ossification, and Skin Breakdown

Erin N. Sabe
University of North Dakota

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TRAUMA REHABILITATION OF TRAUMATIC BRAIN INJURY:
A PHYSICAL THERAPY PERSPECTIVE IN THE MANAGEMENT
OF MUSCULAR COMPLICATIONS, HETEROTOPIC
OSSIFICATION, AND SKIN BREAKDOWN

by

Erin Nicole Sabe
Bachelor of Science in Physical Therapy
University of North Dakota, 1995

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1996
This Independent Study, submitted by Erin Nicole Sabe in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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(Faculty Preceptor)

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(Chairperson, Physical Therapy)
PERMISSION

Title Trauma Rehabilitation of Traumatic Brain Injury: A Physical Therapy Perspective in the Management of Muscular Complications, Heterotopic Ossification, and Skin Breakdown

Department Physical Therapy

Degree Master of Physical Therapy

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Signature __________________________

Date __________________________
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Finally, thank you to the Lord, Jesus Christ, for all of His blessings and unconditional love. I will always know that, no matter what, Jesus will always love me.
ABSTRACT

Traumatic brain injury (TBI) is any combination of focal and/or diffuse central nervous system dysfunction, both immediate and delayed, at the brainstem level and above. The dysfunctions, which are not developmental or degenerative, are due to the interaction of any external forces and the body, violent movements of the body, infection, toxicity, surgery, and non-age related vascular disorders. In the United States, TBI has reached epidemic proportions and is the leading killer and cause of disability in children and young adults.

The TBI survival rate is increasing due to life-saving technology. Survivors will face extensive rehabilitation services, which have been proven more beneficial if begun in the trauma center or Intensive Care Unit (ICU). Physical therapists in newly accredited level I or II trauma centers may be unfamiliar with trauma rehabilitation management of the TBI survivor.

The purpose of this study is to review the literature regarding the incorporation of physical therapy into the trauma rehabilitation of patients with TBI to affect the specific secondary complications following injury including: neurologically imposed muscular changes, heterotopic ossification, and skin breakdown. Trauma rehabilitation will be discussed and examples of techniques
will be explored. Injury severity and outcome measures will also be briefly discussed.

The information resulting from this study will aid physical therapists in the competent, efficient, and effective trauma rehabilitation of patients with TBI.
CHAPTER I

INTRODUCTION

In the time it takes one to read this paragraph, someone in the United States will have sustained a head injury. Every five minutes, one of those people injured will die and another will become permanently disabled. In fact, traumatic brain injury (TBI) is the leading killer and cause of disability in children and young adults.\textsuperscript{1,2} According to the Brain Injury Association of Connecticut,\textsuperscript{1} acquired traumatic brain injury is defined as,

Any combination of focal and/or diffuse central nervous system dysfunction, both immediate and delayed, at the brainstem level and above. These dysfunctions are acquired through the interaction of any external forces and the body, including blows to the head, violent movements of the body, infection, toxicity, surgery, and vascular disorders not associated with aging. These dysfunctions are not developmental nor degenerative.

In the United States, TBI has reached epidemic proportions with from two million to seven million cases reported annually in the United States. (Variability depends upon the survey technique employed).\textsuperscript{3-7} Approximately 500,000 of
those injured will be admitted to the hospital, and 50,000 to 90,000 of those admitted will have suffered moderate to severe head injuries.

Demographically, men suffer TBI three times more often when compared to women. The adolescent and young adult age groups between the ages of 15 and 24 years are more prone to TBI. Most sufferers of TBI are single and fall into the lower socioeconomic groups. Many will have a history of alcohol or drug use or may have experienced psychiatric care prior to their injury.

Years ago, the majority of individuals suffering a moderate or severe TBI would have died; however, modern life-saving technology and life-lengthening interventions have increased the survival rate. The majority of survivors of TBI are under 30 years of age and two-thirds of them will live a normal life-span. They may face 5 to 10 years of intensive intervention with an estimated cost of $4 million as well as additional costs, depending upon their level of function, for lifelong assistance in living.

Traumatic brain injury is a progressive process made up of two major components. Primary damage is sustained at the moment of impact, while secondary damage occurs as the body reacts to the primary insult. Primary damage is due to the soft tissues of the brain sliding and striking against the rigid skull, causing focal damage to the lobes of the brain as well as axonal injuries due to shearing forces. Secondary reactions may include enlargement of hematomas and resultant increased intracranial pressure (ICP) leading to tissue ischemia and death. Increase ICP may also lead to herniation and
subsequent compromise of the brainstem and its functions leading to a higher risk of mortality. The secondary effects of TBI may be demonstrated within minutes, hours, or days following the initial injury. Some specific secondary complications that may result include: motor control problems, skin breakdown, heterotopic ossification, muscle disuse atrophy, and reflexive posturing. The result of these and other secondary complications may prolong or inhibit the recovery process for the TBI patient.

Overall mortality from head injury has decreased, however, from 70% in the 1970s to around 30% currently, according to Marshall et al. Palter et al credited this decrease in mortality to “shorter transport times to definitive care, more aggressive treatment of intracranial hypertension, better understanding and treatment of secondary factors that influence outcome, and improved overall care in the intensive care unit.” Although primary injury is irreversible, optimal and timely treatment of secondary, reversible damage may offer an increased chance of recovery and improved outcome with less disability. Therefore, the goals of treatment in the intensive care unit and trauma center are to prevent secondary injury, decrease mortality, and optimize functional outcome; subsequently decreasing costs and improving the quality of life for traumatic brain injury survivors.

Palter et al stated, “The ultimate measure of recovery from head injury should focus on good recovery rather than severely disabled survivors.” The rehabilitation continuum of care, consisting of the acute care phase; intermediate
or acute rehabilitation phase; and late, postacute rehabilitation phase, is primarily responsible for the good recovery of individuals with TBI and has been proven beneficial.\textsuperscript{2,5,9,12,14} The goal of rehabilitation in the acute care phase is to focus on the prevention of complications and the development of an early prognosis and is often termed \textit{early intervention} or \textit{trauma rehabilitation}. The \textit{intermediate/acute rehabilitation therapy}, provided in a rehabilitation unit after transfer from acute care, is intended to restore previous function and facilitate the re-acquisition of skills. \textit{Postacute rehabilitation}, which occurs in specialized group-rehabilitation facilities, includes the learning and integration of adaptive behavior and the facilitation of functional reentry into the home, community, or workplace.\textsuperscript{11,12}

Mackay\textsuperscript{12} concluded that the utilization of a formalized trauma rehabilitation program for trauma survivors was substantially beneficial; however, little information has been available regarding the benefits of trauma rehabilitation and traumatic brain injury specifically. In a separate study, Mackay et al\textsuperscript{13} indicated that “rehabilitation medicine will have to meet the challenges of the TBI population to ensure quality of life for these individuals.”\textsuperscript{(p635)} It is obvious, then, that for physical therapists to meet this challenge, every effort must be made to become competent, efficient, and effective in the early intervention and trauma rehabilitation management of TBI survivors.

The purpose of this independent study is to review the literature regarding incorporation of physical therapy into the early intervention and trauma
rehabilitation of patients with TBI to affect the specific secondary complications following injury including: muscular changes imposed by spasticity, heterotopic ossification, and skin breakdown. Trauma rehabilitation will be defined and discussed regarding appropriate time frames, personnel involved, and projected outcomes. Secondly, physical therapy intervention will be discussed, including treatment implications specific to the patient in an intensive care unit (ICU) and general indications and contra-indications for physical therapy intervention relative to the secondary complications of TBI. Examples of treatment techniques used to control specific complications and devices for measuring and assessing current patient status, progression of recovery, and outcome of individuals with TBI will be presented.

With increasing numbers of recently accredited level I or II trauma centers, especially throughout the Midwest, more physical therapists in these centers are encountering the trauma patient for the first time. This independent study is intended to assist physical therapists in the effort to become competent, efficient, and effective in the early intervention and trauma rehabilitation management of the TBI survivor.
CHAPTER II
TRAUMA REHABILITATION

The benefits of trauma rehabilitation or early intervention regarding the care of patients with traumatic brain injury are being documented with increasing frequency.\(^5,11-14\) However, for many, trauma rehabilitation is not a clearly defined concept. The purpose of this chapter is to define and describe this concept and to discuss the appropriate time frames for early intervention, personnel involved, and projected outcomes relative to previous efficacy studies.

**What Is Trauma Rehabilitation?**

Trauma rehabilitation is defined by Mackay et al\(^{13}\) as, "early aggressive rehabilitation during acute hospitalization,"\(^{12}\) which most frequently occurs in the intensive care unit (ICU).\(^{12}\) This definition provides for distinction of trauma rehabilitation and/or early intervention as a separate entity from acute rehabilitation. Trauma rehabilitation begins in a trauma center or other primary care hospital prior to transfer of the patient to a rehabilitation unit or rehabilitation hospital. Acute rehabilitation differs from trauma rehabilitation in that it occurs in a specialized unit or hospital after transfer from the primary care hospital.\(^{12}\) Acute rehabilitation, designed as intensive therapy for short periods of time, is intended for responsive, actively recovering individuals. In contrast,
subacute rehabilitation, which is predominantly provided in nursing homes or extended care facilities, is a less intensive treatment programming than other levels and is designed for slower-recovering or minimally responsive patients. The primary focus of care for the TBI victim in the ICU encompasses "life-enabling" treatment and stabilization of the patient's medical and neurological status. However, provisions must be made for the patient in anticipation of the patient's survival following TBI. Therefore, rehabilitation must be considered as a part of trauma rehabilitation. Specific components of trauma rehabilitation make it a unique feature of the rehabilitation continuum of care for patients with TBI. These major characteristics include early and aggressive trauma rehabilitation, family education and involvement, and persistent and consistent coordination of care between medical and rehabilitation professionals. Mackay et al described many vital components of a formalized early intervention program at a trauma center which are described in Table 1.

**What Are The Goals Of Early Intervention?**

The ultimate purpose of patient care in the ICU for the TBI victim is the management of the patient's primary injuries while reducing secondary complications in a structured environment. The improved overall care of the TBI patient in the ICU should then decrease the length of stay (LOS) and resultant costs of care for the patient while facilitating improved quality of life and optimizing outcomes.
Table 1.— Components of a Formalized Trauma Rehabilitation Program.\textsuperscript{12,13}

<table>
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<td>Aggressive trauma rehabilitation initiated within 24 hours of admission</td>
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<td>Multidisciplinary patient rounds to facilitate information sharing and planning</td>
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<tr>
<td>Staff educational programs</td>
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<tr>
<td>Family brain injury education program</td>
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<tr>
<td>Ongoing family access to professional team members on both a formal and an informal basis</td>
</tr>
<tr>
<td>Provision of ongoing consistent medical/rehabilitative and prognostic information to the family</td>
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<tr>
<td>Facilitation of family members as active participants in the treatment program</td>
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<tr>
<td>Ongoing psychosocial support</td>
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<td>Discharge planning by team members and family initiated early in hospitalization.</td>
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How does physical therapy intervention become involved in achieving the goals established in the ICU? The rehabilitation team strives to assist the patient to maximize the patient's role fulfillment and independence in his/her environment, all within the limitations imposed by the underlying pathology and impairments and the availability of resources. Secondly, the rehabilitation team attempts to help the person to make the best adaptation possible to any difference between roles achieved and roles desired.

In order to achieve these long-term goals, specific short-term goals must be established. A primary short-term goal relevant to the rehabilitation initiated in the ICU is prevention of secondary complications. Many of the secondary complications resulting from TBI and the subsequent prolonged immobilization may be affected by physical therapy intervention. Powel concluded, "early rehabilitation intervention in the TBI patient has resulted in decreased contractures, decreased posturing, earlier mobilization, and a better understanding of the recovery stages a TBI patient experiences while in a trauma center." For example, specific physical therapy techniques and procedures may inhibit decubitus ulcer formation, edema, and contractures. Spasticity resulting from craniocerebral trauma may also be controlled with various physical therapy intervention techniques. Pulmonary hygiene is another component of early care in which physical therapists may become involved. Mackay et al., in describing a formalized program, indicated, "This goal oriented intervention, which continued throughout the primary care hospital
admission, involved early intervention approaches from both a rehabilitation and preventive viewpoint.\(^{(p13)}\) Examples of treatment components include structured multisensory stimulation, orientation, exercise, and positioning to decrease posturing and help prevent contractures and sensory deprivation. To provide improved overall care of the patient with TBI in the ICU, it is important for physical therapists to have a better understanding of the treatment of secondary factors that influence outcomes.\(^9\)

**What Time Frame Constitutes Early Intervention?**

TBI may cause significant long-term physical, emotional, and financial stress on patients and their families.\(^3\) Considering the individual and societal cost of injury, time lines of rehabilitation intervention are important in cost containment.\(^{12}\) Cobble et al\(^{11}\) reported, "Cost effective rehabilitation in brain disorders depends on appropriate timing of interventions."\(^{(p324)}\) Although functional improvements may occur for many months or years following injury, Cope\(^{14}\) stated, "a missed opportunity to retrain injured neurological mechanism in a timely fashion may to some extent be an opportunity lost forever. . ."\(^{(p436)}\) Schwartz et al\(^{19}\) advocated that rehabilitation services can and should be provided for the individual with severe brain and body injuries, stating, "Once a person is stabilized in the emergency department, the ICU becomes the starting point for initiation of rehabilitation services for the patient with severe trauma."\(^{(p32)}\) Hetherington et al\(^{20}\) shared in the endorsement of early intervention
by stating, "rehabilitation should begin early after the accident . . . it should be provided by a formalized team, and not just one person." (PS28)

The Multidisciplinary Team Approach

"The key to effective rehabilitation is good organization with a comprehensive team approach working towards the common goals and aims." (PS27)

The fast-paced ICU environment demands continued, congruent interaction of all patient-care providers or members of the interdisciplinary team. Sherburne et al 10 reported that although rehabilitation in the ICU is not new, the formalized multidisciplinary team approach to rehabilitation within a specialized care unit is novel. Maintenance of a team approach will ultimately enhance every team member's efforts, including the patient's. Mackay et al 13 believed the multidisciplinary rehabilitation approach in the ICU, will help ensure for the patient the opportunity for maximal recovery by increasing cognitive and physical skills. This will enhance a patient's ability to participate in and benefit from continued aggressive programming when transferred to a rehabilitation facility. Ideally, the team approach will provide holistic treatment for patients with TBI and for the many injuries and deficits they may have.

The multidisciplinary team may include physicians, nurses, occupational therapists, physical therapists, speech pathologists and audiologists, social workers, psychologists, neuropsychologists, dietitians, respiratory therapists, pastoral care providers, and pharmacists. 2,5,10,11,13,15,16,20 The members of the
multidisciplinary team and their individual roles and responsibilities are described in Table 2. "All of these 'essential disciplines' are mobilized to address acute and chronic needs of the injured person." Each member of the patient care team works together to achieve common goals including: (1) stabilization of the patient medically; (2) neurological progression of the patient; (3) education, support, and guidance for the family through the crisis period. "The rehabilitation team becomes an ally of medical intervention and shares the basic goals of preservation of organ system function, prevention of secondary medical complications, and restoration of function." The continuity of care among the various professionals is ensured by consistent and ongoing communication throughout the rehabilitation team. Information regarding life-threatening changes in vital signs, progression of treatment, and general evaluative findings must be shared among the team members. The protocols of care used by each member should be interdependent to allow for standardized, consistent care. Many authors advocate weekly trauma team meetings and rounds to facilitate communication and uninterrupted provision of care. Family issues may also be discussed during team meetings, as family members are encouraged to become vital components of the team. Together, the team provides an ongoing assessment, establishment of goals, and construction of programs to maximize the patient's recovery potential. Undefined areas of treatment between professions should be acknowledged and shared so they may be addressed constructively. Hall
<table>
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<th>TRAUMA TEAM MEMBER</th>
<th>RESPONSIBILITIES</th>
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| Primary Nurse            | 24 hour responsibility  
Communication mediator  
Coordinator of care  
Patient and family educator |
| Physiatrist              | Consultation initiates rehabilitation  
Makes recommendations regarding treatments of various disciplines  
Orders diagnostic studies |
| Emergency Medicine Physician | Manages medical care to promote stabilization of patient condition upon admission  
Initial diagnosis and treatment of medical problems |
| Social Services          | Liaison between families and physician  
Provides patient and family counseling and resources  
Initiates discharge planning  
Assists with financial planning |
| Physical Therapist       | Maintains ROM  
Promotes mobilization  
Prescribes positioning program  
Provides relaxation techniques  
Prevents secondary complications  
Assist with pulmonary hygiene  
Promotes strength, coordination, and mobility. |
| Respiratory Therapist    | Provides ventilation management |
| Occupational Therapist   | Maintain ROM,  
Facilitate Functional ADL skills  
Assess cognition and perception  
Provide positioning and splinting programs. |
| Dietitian                | Consults with Rehab team to determine best method of nutritional management. |
| Speech Pathologist and Audiologist | Stimulate and promote communication  
Assess swallowing. |
| Psychologist             | Assess and intervene with patient and family  
Teach coping skills and adaptation  
Assist the grieving process  
Establish behavior programs |
| Neuropsychologist        | Provides in-depth assessment of cognitive function. |
| Pharmacist               | Provide prescribed medications  
Educate family and patient re: meds, effects, and side-effects |
| Family                   | Assist caregiver-patient bond  
Provide support for patient  
Assist in care for patient |
| Patient                  | Central focus of care as and entire person, not just a brain injury. |
emphasized the following overall objectives of the head injury team: increase the ease of referral, facilitate communication between team members and families, begin earlier discharge planning, minimize duplication of treatment across services, involve the family earlier, standardize patient assessment and treatment, engage in research to examine outcome from head injury, and help determine the patient's prognosis. Congruency of team care will benefit the patient through staff and family awareness of the total continuum care for the patient with a TBI. The team members should benefit from the shared knowledge and experience of the team of health care professionals.²²

The literature regarding demonstrated improvement of TBI patient care related to early trauma rehabilitation in the ICU is dominated by various landmark studies. Many authors²,¹²-¹⁴,¹⁸,²¹-²⁴ compared the time of rehabilitation onset to the patient's LOS, Disability Rating Scale (DRS) score, cognitive outcome, and development of secondary complications when considering the benefits of early intervention and trauma rehabilitation.

Cope and Hall et al ¹⁴ demonstrated that formally rehabilitated patients with severe TBI experienced fewer secondary complications, abbreviated rehabilitation stays, and subsequently less cost of care when compared with a second group of equally matched, untreated TBI patients. The authors indicated that approximately $40,000 was saved per patient, per rehabilitation episode, if referral to rehabilitation was made less than 35 days after injury. Two patient groups, matched for age, length of coma, disability level, and computed
tomography (CT) scan appearance, were grouped as “early” if rehabilitation was initiated less than 35 days after injury and “late” if rehabilitation initiation was greater than 35 days after injury. The authors found that the LOS of the “late” group was almost two times that of the “early” group. Length of stay was reduced from 55.8 to 20.9 days in an acute care hospital and from 88.8 to 43.5 days in the rehabilitation hospital. However, a significant difference in outcome that related to the decreased LOS two years post-injury was not evident. This study supports the assumption that rehabilitation is most efficient if it is early and intense.

Hall and Wright\textsuperscript{25} replicated the study by Cope and Hall.\textsuperscript{14} Their findings correlated with those of Cope and Hall. The LOS was decreased by 32 days for the “early” versus the “late” groups and DRS were mild for “early” and moderate for “late” rehabilitation intervention groups.

Spettel et al,\textsuperscript{23} in a study comparing the time of rehabilitation admission and severity of trauma with the effect on brain injury outcome, referred to two animal studies that demonstrated the possibility of a critical period of neurological recovery when rehabilitation intervention strategies may be most effective. Spettel\textsuperscript{23} referred to several authors regarding CNS recuperation from injury.

Stein\textsuperscript{26(p324)} reported a likelihood that there may be a critical period for sparring certain behavioral functions that depend on the frontal cortex. Wall and Egger\textsuperscript{27} have shown that there may be a discrete
and limited period during which new, functional CNS connections may emerge in differentiated nuclei. Other studies have demonstrated that early training of experimentally lesioned animals produces greater recovery than no training or delayed training. Therefore, the sooner remedial rehabilitation services is initiated for the survivors of TBI, the better for the patient who needs intensive, inpatient rehabilitation. Further, a quick move into intensive rehabilitation will decrease the expense of the rehabilitation efforts.

Greenburg et al\textsuperscript{28} concluded that long-term functional outcome for head-injured patients is improved if secondary complications are avoided. This was demonstrated by the use of multi modal evoked potentials. When secondary complications occurred, the number of patients who made good recovery with mildly abnormal multi modal evoked potentials declined from 100\% to 37\%. Therefore, the physical therapist's role in preventing secondary complication is a major factor in the ICU setting.\textsuperscript{18}

Mackay et al\textsuperscript{13} demonstrated that patients of a formalized trauma rehabilitation program had an acute hospital LOS about one-third as long as patients in a non-formalized program. This study also demonstrated that higher cognitive levels were achieved upon discharge, and higher percentages of discharges were to home rather than extended care facilities (94\% and 57\%, respectively). Mackay attributes the success of formalized early intervention to the comprehensiveness of the program. Specific components of the program
employed in the study that make it comprehensive include effective discharge planning, better treatment programs that prepare patients for structured therapy programs, and coordinated efforts of a multidisciplinary team to prevent secondary insults and complications and to improve quality of care.¹²

Results of a study performed by Rappaport et al.²⁹ suggested that an increased amount of time between injury and admission to a rehabilitation hospital results in decreased long-term outcomes. Ideally, early rehabilitation intervention will facilitate the recovery necessary during the period following injury and prior to formal rehabilitation hospital admission.

Morgen et al.² also supported trauma rehabilitation, stating:

[É]arlier trauma rehabilitation (less than or equal to 7 days post-injury) was associated with better outcomes in the areas of cognition, perception, and motor skills at discharge from the hospital. Those patients displayed marked improvement after a hospital stay averaging 24 days, compared to an averaged LOS of 45 days for patients with rehabilitation intervention beginning 8 or more days post-injury. With patients admitted in coma, the average LOS improved from 75 days to 31 days with trauma rehabilitation.⁽⁶⁾⁽³⁽⁶⁾⁾

Finally, Bontke¹⁵ and Hall²² implicated the use of the multidisciplinary team and a formalized TBI trauma rehabilitation program to positively impact patient outcome and LOS following severe TBI.
All of the authors previously mentioned indicated the need for controlled studies regarding the efficacy of dedicated trauma rehabilitation programs. Most of the studies demonstrated improvements during acute rehabilitation; however, rapid spontaneous recovery after TBI may have confounded treatment effects noted during this study. Further, this author was unable to find any literature substantiating the benefit of early rehabilitation on long-term outcome from brain injury.

It seems evident that trauma rehabilitation is a small, but vitally integral link in the continuum of care for the patient with a traumatic brain injury. This fact is demonstrated in Figure 1 depicting the flow of rehabilitation services for severe traumatic head injury patients.
Occurrence of Injury

↓

Emergency Medical Care and Transport

↓

Trauma Center

↓

Acute Treatment

<table>
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<tr>
<th>Neurobehavioral Program</th>
<th>Acute Coma Management Program</th>
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<tr>
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<td>Rehabilitation Subacute Rehabilitation Program</td>
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↓

Postacute Treatment

| Comprehensive Outpatient Day Treatment | Transitional Living Center (residential treatment) | Nursing Home Based Subacute Rehabilitation Program |

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**Fig. 1.—Flow of Rehabilitation Services for Severe TBI patients.**

Adapted from Bontke et al.\textsuperscript{15}
CHAPTER III

PHYSICAL THERAPY INTERVENTION

The entire multidisciplinary rehabilitation team involved with the early intervention and care of the TBI patient will function to achieve an overall goal of preventing medical complications and increasing the patient’s functional capacity. The physical therapist’s role in achieving this goal is to “anticipate the long-term outcomes that serve as the measure of return to a good quality and productive life for the brain injury survivor.”30(p492) Gill-Body et al9 indicated that the physical therapist’s complete understanding of common medical management elements involved with TBI patient care is vital to ensure quality care. The physical therapist is responsible for developing an intervention program that is recognized and integrated into the patient’s care by all team members.

It is important that physical therapists should focus on the prevention of secondary complications.2,5,15,19 Morgen et al2 and Schwartz et al19 described potential complications that may affect the recovery of TBI victims. Along with the most common complication of pneumonia and other respiratory problems, hypertonicity of muscles, contracture formation, heterotopic ossification, and pressure ulcers may develop.
This chapter will address specific treatment implications the intensive care unit (ICU) physical therapist may encounter. The chapter will include a description of the general presentation of the patient with TBI. Common medical equipment found in the ICU will be discussed regarding its purpose and relevance to physical therapy treatment and specific features of the initial evaluation will be outlined.

**Treatment Implications Specific To The ICU**

The ICU is a very fast paced location for patient care, and although benefits have been reported involving early patient rehabilitation, the patient's medical stability is of utmost importance to the provision of care. Many different care providers will need to access the patient, necessitating cooperation and flexibility among care providers. This may cause severe constraints on the amount of time available for the physical therapist to evaluate and treat the patient.\(^5\)

Schwartz et al\(^{19}\) related that scheduled therapy sessions in the ICU is an unrealistic expectation. Diagnostic tests and procedures will take precedence over therapy sessions. Sedatives or paralyzing agents may severely limit the therapy treatment plan. Further, the patient's general condition will cause an inability to tolerate prolonged procedures or interactions with health care providers.\(^5\) A composite of indicators relative to the termination or moderation of therapy interventions is summarized in Table 3.\(^{19}\)
Table 3.— Clinical Findings Signifying a Deterioration of the Patient’s Condition.\textsuperscript{19}

<table>
<thead>
<tr>
<th>Clinical Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change from decorticate or decerebrate posturing to flaccidity</td>
</tr>
<tr>
<td>Previously responsive pupils become fixed and dilated</td>
</tr>
<tr>
<td>Cushing’s Triad (increased blood pressure with a significant decrease in pulse and respiration)</td>
</tr>
<tr>
<td>Unilateral or bilateral pupillary dilation</td>
</tr>
<tr>
<td>Decreased blood pressure and increased pulse and cardiac arrythmias.</td>
</tr>
</tbody>
</table>
Communication with the patient's nurses regarding vital signs, neurological status, and medications should precede any patient/therapist interaction. The patient's nurse is responsible for permitting any rehabilitation team member access to treat the patient, and that responsibility should always be respected.

Specific medications may be used for the patient in the ICU following a TBI. Initially, tranquilizers may be prescribed to treat agitation. Sedation may also be required for the patient to endure specific procedures or tests. Cobbel et al.\textsuperscript{11} concluded that sedative drugs are often contraindicated and misused in the ICU for the TBI patient population because of the drugs' inhibiting effects on the patient's progression through the levels of consciousness. Bennett et al.\textsuperscript{3} stated that sedating medications, such as neuroleptics and minor tranquilizers, lead to confusion, cause decreased ability to learn, and affect memory. Drugs used for other indications, such as other CNS depressants, antihypertensive drugs, and GI tract drugs, may also have sedating side effects. It is important for the physical therapist to be familiar with the types and effects of medications prescribed when treating the TBI patient in the ICU. Table 4 lists various medications commonly used in the ICU, their indications, and side effects.

Last, but not least, the family of the patient with a TBI in the ICU is a vital component of the complete rehabilitative therapy team. Cobbel et al.\textsuperscript{11} indicated, "Early family involvement in the rehabilitation process is crucial in setting appropriate goals, overcoming denial, and learning to deal with the behavior of
<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose/Function</th>
<th>Contraindications</th>
<th>Side Effects</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elavil</td>
<td>Antidepressant</td>
<td>Abnormal heart beat</td>
<td>Altered BP and blood sugar, Diaphoresis, dry mouth, weakness, tremors, arrhythmia, sedation</td>
<td>CNS depressant that functions to decrease psychological depression</td>
</tr>
<tr>
<td></td>
<td>Level II/III to ñ arousal; higher levels to ø agitation</td>
<td>Urinary retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trofranil</td>
<td>Antidepressant</td>
<td>Myocardial Infarction</td>
<td>Altered BP and blood sugar, confusion, parasthesia or tingling, ataxia, tremors, dry mouth, blurred vision</td>
<td>Stimulation of CNS</td>
</tr>
<tr>
<td>Ritalin</td>
<td>Heighten arousal and alertness</td>
<td>Drug dependence history ñ BP</td>
<td>Ataxia, insomnia, abnormal heart beat, N, blurred vision</td>
<td>Monitor BP tolerance to the drug effect</td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>Anticonvulsant Narcotic</td>
<td>Severe trauma, severeñ BP, Drug dependence history, Uncontrolled diabetes</td>
<td>Lethargy and sedation, ataxia, nystagmus, osteomalacia, habitual</td>
<td>Gradually discontinue</td>
</tr>
<tr>
<td>Thorazine</td>
<td>Tranquilization</td>
<td>Comatose states Polypharmacy affect with large amounts of CNS depressants</td>
<td>Drowsiness, jaundice, ñ BP, extrapyramidal neuromuscular reactions, dystonia and pseudo-parkinsonism, possible hepatotoxicity</td>
<td>Unknown precision of the mechanism of function</td>
</tr>
<tr>
<td>Haldol</td>
<td>Tranquilization</td>
<td>Severe CNS depression or comatose states, Parkinson’s Disease</td>
<td>Extrapyramidal neuromuscular reactions pseudoparkinsonism, restlessness, dystonia, drowsiness</td>
<td>Dopamine blocker</td>
</tr>
<tr>
<td>Name</td>
<td>Purpose/Function</td>
<td>Contraindications</td>
<td>Side Effects</td>
<td>Comments</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
<td>---------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Mellaril</td>
<td>Tranquilization, Psychotic disorder management</td>
<td>Severe CNS depression or comatose states</td>
<td>Infrequently drowsiness, extrapyramidal neuromuscular reactions</td>
<td></td>
</tr>
<tr>
<td>Navane</td>
<td>Tranquilization, Psychotic disorder management</td>
<td>Circulatory collapse, comatose states, CNS depression</td>
<td>Drowsiness, restlessness, agitation</td>
<td>Possible induction of convulsions</td>
</tr>
<tr>
<td>Artane</td>
<td>An adjunct to treatment of parkinsonism, Control of extrapyramidal disorders induced by CNS pharmacologics</td>
<td>Used cautiously in cardiac, liver, kidney or BP patients</td>
<td>Dry mouth, blurred vision, dizziness, N, nervousness</td>
<td>Empirical determination of size and frequency of dosage</td>
</tr>
<tr>
<td>Dilantin/Phenotoin</td>
<td>Anticonvulsant Antiarrhythmic</td>
<td>Hypersensitivity</td>
<td>Rash, hyperglycemia, osteomalacia, nystagmus, ataxia</td>
<td>Gradually discontinue</td>
</tr>
<tr>
<td>Tegretol</td>
<td>Anticonvulsant</td>
<td>Liver abnormalities</td>
<td>Complete Blood Count abnormalities, rash, altered cardiac function, sedation</td>
<td>Hepatic complications may result with long-term therapy</td>
</tr>
<tr>
<td>Name</td>
<td>Purpose/Function</td>
<td>Contraindications</td>
<td>Side Effects</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dantrium/</td>
<td>Spasticity control</td>
<td>Liver abnormalities, compromised pulmonary and cardiac function</td>
<td>Drowsiness, dizziness, weakness and fatigue, D, possible hepatotoxicity</td>
<td>Discontinued if not effective in 4.5 days&lt;br&gt;MM contractile mechanism directly affected adversely</td>
</tr>
<tr>
<td>Dantrolene Sodium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Lioresal</td>
<td>General CNS depressant</td>
<td>Monitor use in patients with diabetes and epilepsy</td>
<td>Transient drowsiness, dizziness, fatigue, urinary urgency, C, N, V, blurred vision, HA, disorientation, parasthesia, tremor</td>
<td>80 mg/day maximum&lt;br&gt;Hallucination may result from abrupt withdrawal</td>
</tr>
<tr>
<td>(Baclofen)</td>
<td>Relieves mm spasm, clonus, and rigidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valium/</td>
<td>Spasticity and anxiety control, Skeletal mm relaxant</td>
<td>Children &lt; 6 months of age</td>
<td>Drowsiness, fatigue, ataxia, HA, confusion, depression, blurred or double vision, rashes, incontinence, C</td>
<td>Enhanced Dilantin effects&lt;br&gt;Physical and psychological dependence Will ø BP</td>
</tr>
<tr>
<td>Diazepam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ativan/</td>
<td>Sedative/hypnotic Antianxiety</td>
<td>Narrow angle glaucoma, psychosis, pregnancy, children &lt; 12 yo, drug dependence history, COPD</td>
<td>Dizziness, drowsiness, confusion, HA, anxiety, tremors, depression, weakness, C, N, V, orthostatic hypotension, tachycardia</td>
<td>CNS depressant, especially in the limbic and reticular activating system</td>
</tr>
<tr>
<td>lorazepam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. — Common Pharmacological Agents Used With Head Injured Patients (Continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose/Function</th>
<th>Contraindications</th>
<th>Side Effects</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didronel/etidronate disodium</td>
<td>Parathyroid agent, ð bone resorption and new bone development</td>
<td>Pathologic fractures, pediatrics, colitis, severe renal disease</td>
<td>N, D, bone pain</td>
<td>Inhibits bone formation with HO</td>
</tr>
<tr>
<td>Xylocaine/lidocaine</td>
<td>Antidysrhythmic</td>
<td>Severe heart block, supraventricular dysrhythmia, Adams-Stokes syndrome, Wolff-Parkinson-White syndrome</td>
<td>HA, Dizziness, involuntary movement, confusion, tremor, drowsiness, euphoria, convulsions</td>
<td>Decreases the automaticity of cardiac function to improve regulation</td>
</tr>
<tr>
<td>Mannitol</td>
<td>Osmotic Diuretic</td>
<td>Active intracranial bleed, anuria, severe pulmonary congestion, edema, severe dehydration, progressive heart or renal failure</td>
<td>Diuresis, thirst, dizziness, HA, convulsions, rebound ñ ICP, confusion, N, V, D, blurred vision, loss of hearing</td>
<td>Used to treat ñ ICP</td>
</tr>
<tr>
<td>Dolophine/methadone</td>
<td>Narcotic analgesic Suppressant</td>
<td>Hypersensitivity or narcotic addiction</td>
<td>Drowsiness, dizziness, confusion, HA, sedation, N, V, C, cramps, blurred vision, diplopia</td>
<td>CNS depressant</td>
</tr>
<tr>
<td>Name</td>
<td>Purpose/Function</td>
<td>Contraindications</td>
<td>Side Effects</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Metubine/metocurine iodide</td>
<td>Neuromuscular blocker</td>
<td>Hypersensitivity</td>
<td>ñ or δ BP, respiratory alterations</td>
<td>Relaxes skeletal mm for facilitation of intubation, ventilation or fracture reduction</td>
</tr>
<tr>
<td>Nurcuron/vecuronium bromide</td>
<td>Neuromuscular blocker</td>
<td>Hypersensitivity</td>
<td>MM weakness, possible paralysis, respiratory alterations</td>
<td>Relaxes skeletal mm for facilitation of intubation, ventilation or fracture reduction</td>
</tr>
<tr>
<td>Pavulon/pancuronium bromide</td>
<td>Neuromuscular blocker</td>
<td>Hypersensitivity</td>
<td>ñ or δ BP, respiratory alterations, weakness, prolonged skeletal mm relaxation</td>
<td>Relaxes skeletal mm for facilitation of intubation, ventilation or fracture reduction</td>
</tr>
<tr>
<td>Nembutal/pentobarbital</td>
<td>Preanesthetic, sedation/hypnotic</td>
<td>Hypersensitivity, respiratory depression, liver or renal impairment, uncontrolled pain</td>
<td>Lethargy, slurred speech, CNS depression, N, V, D, C, respiratory depression</td>
<td>CNS depressant</td>
</tr>
<tr>
<td>Pentothal/thiopental</td>
<td>Anesthetic, no analgesia, Anticonvulsant, hypnotic</td>
<td>Hypersensitivity, status asthmaticus, hepatic dysfunction</td>
<td>Respiratory depression, retrograde amnesia, shivering, cold mm an injection site, mm irritability</td>
<td>CNS depressant</td>
</tr>
</tbody>
</table>

*Adapted from O’Sullivan and Schmitz and Mosby

*Key: ñ=increased, δ=decreased, BP=blood pressure, N=nausea, D=diarrhea, C=constipation, V=vomiting, HA=headache, CNS=central nervous system, COPD=Congestive Obstructive Pulmonary Disease, HO=heterotopic ossification, ICP=intracranial pressure, MM= muscle.
the patient with a brain disorder. Generally, the family will become the major care giver following discharge, necessitating the provision of information, education of rehabilitation techniques, interaction, and collaboration with family during the acute phase of hospitalization. The family may also assist the rehabilitative team in forming the patient/therapist bond. The family may provide important information such as patient nicknames; names of family members, friends, and pets; patient's premorbid personality features; patient hobbies; patient's use of glasses or presence of hearing impairments; possible learning disabilities the patient may have. The family must also be aware of the communication method being used with the patient. Schwartz et al indicated the necessity for all patient care providers, including family, to use a consistent method of communication with the TBI patient to provide consistency for the patient.

**Common Medical Equipment Encountered In The ICU**

Upon entering the ICU, the physical therapist may be overwhelmed by the vast amount and intricate details of the equipment used to monitor and provide care for the TBI patient. However, when the purpose and function of the lines, leads, and tubes being used is understood, the physical therapist will feel more comfortable in providing treatment.

**Airway Management.**—Airway management is one of the most prominent components of patient care. Because TBI may cause disruption of the neural pathways that control respiratory function, shallow, rapid breathing or apnea may result. Walleck described frequent secondary complications that threaten
the patient's hemodynamic status including hypoxia, hypercapnia, and hypotension. These conditions are the cause of secondary injury to the brain and must be avoided with aggressive management in the ICU.

Hypoxia, defined as an arterial oxygen tension (PaO$_2$) level less than 70 mm Hg, indicates the need for intubation and supplementary oxygen.$^{33}$ Hypoxia that is progressive over the first several days after head injury is a poor prognostic sign. Hypercapnia is described as an increased amount of carbon dioxide in the blood.$^{34}$ Hypercapnia may lead to increased intracranial pressure (ICP). Therefore, early airway management may include mild hyperventilation to decrease the level of arterial carbon monoxide tension (PaCO$_2$) to 27-35 mmHg$^{33}$ or 25-30 mmHg$^{35}$. Intracranial hypotension may also worsen the patient's condition because it may lead to brain ischemia due to the contribution to cerebral hypoperfusion. The desired mean arterial pressure is greater than 50 mmHg.$^{33}$ The patient's hemodynamic status will usually be monitored via an oxygen saturation oximeter, a pulmonary artery line (Swan-Ganz catheter), and a central venous catheter (CVC). The pulmonary artery line and CVC may be placed in the subclavian, axillary, or internal jugular area. Muscle stretching at the insertion site is universally contraindicated in these areas. If the insertion site is the subclavian or axillary area, shoulder flexion and abduction beyond 90° is contraindicated. If the placement is the internal jugular area, cervical movement should be limited. A finger or ear oximeter will be used to monitor the patient's oxygen saturation level, which is normally 95% to 100%. The therapist
must be cautious to avoid disconnecting the oximeter clip and should be able to reapply it if necessary.\textsuperscript{5}

Airway management assistance will result in the patient using nasal or oral airway assistance, or the patient may be intubated with an endotracheal tube or tracheostomy.\textsuperscript{5} Nasal or oral tubes are soft tubes that allow suctioning and airway maintenance. There are no contraindications to movement with nasal or oral tubes. The presence of tracheostomies also do not contraindicate movement. If the patient presents with endotracheal intubation, however, cervical range of motion must be limited to avoid dislodging the tube or damaging the trachea. The therapist must also be aware of the weaning process associated with ventilation. Some patients will not tolerate activity well when the ventilator is turned low for weaning, while others may have no difficulty. Communication with the nurse should assist in the treatment planning regarding ventilator weaning.

Monitoring the status of the patient with regard to blood gases and oxygen saturation before, during, and after physical therapy treatment is essential.\textsuperscript{5} Often, a video terminal at the patient's ICU bedside will relay current information regarding the patient's blood pressure (BP), ICP, heart rate (HR), $\text{PaO}_2$, $\text{PaCO}_2$, and $\text{O}_2$ saturation. The therapist must become familiar with the monitoring device and understand how to read the information displayed.

The patient may have suffered chest injuries resulting in a pneumothorax or hemothorax, along with the head injury, necessitating the use of chest tubes.
It is important to keep the drainage apparatus used with chest tubes below the level of the patient’s chest and to assure that the device remains connected to the suctioning power supply. Depending on the location of the chest tubes, upper extremity and trunk movement may be limited and should be considered when providing therapy.\(^5\)

**Intercranial Pressure.**—Palter et al\(^9\) stated that the control of intracranial pressure (ICP) is the most vital component of treatment in patients with severe head injury. Palter described the Monroe-Kelly Doctrine regarding intracranial volume as,

The mainstay of therapy in patients with severe head injury is directed toward control of intracranial pressure. The intracranial volume consists of brain, cerebral spinal fluid (CSF), and blood. If there’s an increase in the volume of one of those components, the pressure will rise, and may lead to brain shift or herniation.\(^{23}\)

Ideally, the ICP should be kept below 20 mmHg.\(^{9,33,36}\) Often, a catheter will be placed into the lateral ventricle to monitor ICP and allow for removal of CSF to assist in the reduction of ICP.\(^9\) If ICP elevations are significant, the swollen brain may lead to hypoxic brain damage due to inhibited fresh blood flow. A monitor must be observed closely to assess the effect that any treatment may have on the ICP. Horn\(^36\) reported that ICP elevations may be exacerbated by treatments such as suctioning, ROM activity, or noxious stimuli. Several
authors\textsuperscript{5,9,19,32,33,37} discussed various methods of controlling ICP. These techniques may include:

- Neutral head and neck alignment should be maintained, occasionally using a stiff collar to prevent turning.
- Elevation of the head of the patient's bed 15° to 30° will optimize cerebral venous drainage. (Controversy exists regarding the use of various positions with head-injured patients.\textsuperscript{5,32})
- Ventilation should be controlled at a PaCO\textsubscript{2} of 27-33 mmHg and a PaO\textsubscript{2} greater than 70 mmHg.
- The patient should be kept normothermic.
- Systolic arterial pressure (SAP) should be maintained between 100-160 mmHg.
- Pharmacological control of increased ICP may be used.

\textbf{Nutritional Management.}\textsuperscript{5}—The TBI patient's nutritional requirements may be met with the use of nasogastric or gastric tube feedings. It may be possible for the feeding tube to be disconnected during rehabilitation treatments. Caution must be taken to avoid pulling on the tubing during treatment. Also, the patient should be positioned such that the head of the bed is elevated 25° to 30° to avoid aspiration during, and for a short time after, nasogastric feedings.

\textbf{Other Equipment.}—Peripheral intravenous (IV) lines may be present to administer medications or fluids. The physical therapist must note the length of the line available to avoid placing tension on it with various movements. If the IV
insertion is located near a joint, weight bearing and ROM must be performed cautiously and limited appropriately. Gill-Body et al\textsuperscript{6} recommended the use of a splint on such a joint, if appropriate.

Arterial lines, which are used for the continuous monitoring of systolic and diastolic blood pressure and for frequent blood draws, may be located at various predominate pulse points including: radial, dorsal pedal, axillary, brachial, and femoral.\textsuperscript{5} Although movement is not contraindicated, the physical therapist must be cautious to limit the repetition and intensity of movement at these points to avoid dislodging the line and possible hemorrhage. The BP transducer used with the arterial lines must be aligned with the patient's heart to function properly. Movement required for ROM and other activities may alter the alignment and cause the alarm to sound. Communication with the nursing staff prior to treatment should alleviate the problem of setting off alarms during physical therapy treatment.

**Evaluation of the Head Injured Patient**

Before any physical therapy treatment occurs, the therapist must provide a thorough evaluation to appropriately assess the patient's condition and allow for appropriate goal establishment and treatment planning.\textsuperscript{16} The evaluative process should be done regularly to indicate changes in strength, movement, and function for the development of new goals.\textsuperscript{20,24} A full neuromuscular assessment and physical intervention may need to be deferred until the patient's condition is somewhat stabilized and no longer requires extremely sedating
drugs or neuromuscular blocking agents.\textsuperscript{32} Mills\textsuperscript{16} has assimilated a comprehensive list of the components of physical therapy assessment involved in the evaluation of the patient with TBI (see Table 5).

The initial evaluation should begin with a medical record review.\textsuperscript{32} The medical record will provide vital information reviewed in Table 6.\textsuperscript{5,19,32}

After reviewing the medical record, the therapist will begin the evaluation by observing the patient. The therapist must assess the patient's positioning, skin integrity, invasive lines, and the presence of various equipment previously described. Boughton et al\textsuperscript{32} stated,

The initial evaluation by the therapist assesses

1) voluntary, active characteristics of limb, head, and eye movements in response to verbal and non-verbal commands and 2) involuntary passive or reflexive features of an impaired motor system, such as posturing, abnormal muscle tone, and reflexive motor behavior.\textsuperscript{(p13)}

Spontaneous responses to environmental stimuli including eye, verbal, and motor responses should be noted. The therapist should elicit and assess the following responses: auditory tracking and localization, visual contact using non-noxious tactile stimuli, resting eye position (to assess cranial nerve involvement), and ability to communicate.\textsuperscript{32} Regarding communication, the patient may be unable to vocalize due to intubation. The therapist must then
Table 5.— Physical Therapy Assessment Components

<table>
<thead>
<tr>
<th><strong>MEDICAL INFORMATION</strong></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Past medical history, onset, and etiology</td>
<td>Results of diagnostic procedures</td>
</tr>
<tr>
<td>Precautions</td>
<td>Ventilatory status</td>
</tr>
<tr>
<td>Swallowing status</td>
<td>Bowel and bladder management</td>
</tr>
<tr>
<td>Skin integrity</td>
<td>Pharmacological interventions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PSYCHOLOGICAL INFORMATION</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous function</td>
<td>Psychological assessment results</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SOCIAL INFORMATION</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supportive family and others</td>
<td>Religious status</td>
</tr>
<tr>
<td>Financial status</td>
<td>Home or discharge environment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>COGNITIVE/COMMUNICATIVE/BEHAVIORAL STATUS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alertness and awareness level</td>
<td>Attention and orientation</td>
</tr>
<tr>
<td>Memory</td>
<td>Communicative ability and means</td>
</tr>
<tr>
<td>Behavior status</td>
<td>Progressive cognitive abilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SENSORIMOTOR FUNCTIONS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual and Auditory ability</td>
<td>Sensation</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>Spatial sense</td>
</tr>
<tr>
<td>Posturing and movement patterns</td>
<td>Reflexes</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>Strength and coordination</td>
</tr>
<tr>
<td>Velocity and quality of movement</td>
<td>Movement strategies</td>
</tr>
<tr>
<td>Functional movement (abnormal or normal)</td>
<td>Endurance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FUNCTIONAL STATUS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed mobility and transfers</td>
<td>Ability to sit and stand</td>
</tr>
<tr>
<td>Static and dynamic balance</td>
<td>Gait over various terrain and stairs</td>
</tr>
<tr>
<td>Progressive physical activities</td>
<td>Functional ability and endurance</td>
</tr>
<tr>
<td>Educational or vocational status</td>
<td></td>
</tr>
</tbody>
</table>

* Adapted from O’Sullivan and Schmidt.  

30
Table 6.— Information Obtained from a Medical Record Review.\textsuperscript{5,19,32}

<table>
<thead>
<tr>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode of accident</td>
</tr>
<tr>
<td>Type and nature of injury</td>
</tr>
<tr>
<td>Extent and location of trauma including associated injuries</td>
</tr>
<tr>
<td>Medical and surgical interventions</td>
</tr>
<tr>
<td>Behavioral and cognitive status</td>
</tr>
<tr>
<td>Status of spinal clearance to establish movement safety</td>
</tr>
<tr>
<td>The patient’s sedation status</td>
</tr>
<tr>
<td>Cardiopulmonary status</td>
</tr>
<tr>
<td>Baseline values, liability and trends of vital signs (HR, BP, resp. rate, and ICP...)</td>
</tr>
<tr>
<td>Laboratory values</td>
</tr>
<tr>
<td>Nursing and physician progress notes</td>
</tr>
<tr>
<td>Patient’s home and social situation</td>
</tr>
<tr>
<td>Current medication, actions and side effects</td>
</tr>
</tbody>
</table>
attempt to elicit yes/no reliability by the use of head shakes, eye blinks, or hand signals. Boughton et al.\textsuperscript{32} recommended avoiding reflexive commands of response such as "squeeze my hand." If it is determined that the patient is responsive, more intensive tactile stimuli is used with each extremity to determine localized response to noxious stimuli.\textsuperscript{32} Techniques such as tactile stimulation, pinpricks, nailbed pressure, sternal rubbing, and supraorbital pressure (in the absence of facial fractures) are used to assess quality, quantity, and symmetry of movement between the patient's right and left sides.

If the patient is unresponsive to the above, pupillary responses must be elicited. The size, reactivity, and resting eye position must be noted. Inappropriate responses may be due to trauma to the eye, cranial nerve involvement, or narcotics or analgesics.\textsuperscript{5} If changes are noted in the size, reactivity, and resting eye movement, immediate medical intervention is indicated.\textsuperscript{32}

Typically, the physical therapist will continue the clinical evaluation with an assessment of the pulmonary system.\textsuperscript{5} This is an extremely important system to address regarding the prevention of secondary complications involving respiration. If the acute care facility and ICU do not use respiratory therapists, pulmonary care often becomes the responsibility of the physical therapist.

The patient's level of cognition must be formally assessed in a standardized manner during every treatment session to determine the patient's ability to interact with the treatment procedures and care providers. Examples of
standardized scales often used in the acute care setting will be further discussed in chapter seven. The physical therapist must assess the patient's cognition regarding four major components as defined by Gill-Body et al.\textsuperscript{5} general arousal level, ability to follow commands, environmental orientation, safety awareness, and judgment.

Following the cognitive assessment, the therapist may initiate the classic physical therapy evaluation of the musculoskeletal and neuromuscular system. Components of the evaluation requiring particular attention include ROM, muscle tone, reflexes, and isolated joint movement.\textsuperscript{32} Often other members of the rehabilitation team, other than the physician, find other orthopedic injuries. These injuries might include acromioclavicular joint separation or clavicle, wrist, hand, ankle, or foot fractures or associated soft tissue injuries.\textsuperscript{15,18,32} Evaluation techniques and components regarding muscle tone changes, heterotopic bone formation, and skin integrity will be discussed in Chapters IV through VI of this paper.

**Assessment and Treatment Planning**

Following a thorough evaluation of the TBI patient, the therapist should have a specific problem list formed and should proceed toward establishing short-term and long-term goals for the patient.\textsuperscript{32} The conventional treatment goals described by Hall et al\textsuperscript{22} include “continuing cardiopulmonary care, maintaining muscle length and joint range of motion to prevent contractures and heterotopic ossification, and monitoring or controlling tone to prevent abnormal
muscle or movement patterns. These items become the framework around which the physical therapist will formulate an appropriate treatment plan.

Functional deficits resulting from body system impairments are the focuses of treatment for patients with TBI. Many intervention strategies may be used by the physical therapist; however, the therapist must always consider the uniqueness of each patient's functional deficits. Treatments must be customized to fit the individual patient's level of function. Mills emphasized this fact in discussing a study which indicated that level 3 and 4 patients on the Rancho Los Amigos Cognitive Scale tolerated many fewer types of treatments in physical therapy as compared with patients at levels 5, 6, 7, and 8. Patients at level 5, 6, and 7 tolerated a much wider range of therapeutic activities and those at levels 7 and 8 were also able to participate in advanced motor activities.

Competent, efficient, and effective provision of care by trauma rehabilitation physical therapists requires a thorough understanding of the information provided in this chapter. The entire rehabilitative team must be confident in their ability to provide care. It is vital to communicate effectively and work as a team to administer an effective continuity of care that will benefit the patient, family, and rehabilitative team.
CHAPTER IV
MOTOR CONTROL COMPLICATIONS AND INTERVENTIONS ASSOCIATED WITH TBI

Traumatic brain injury has the potential to induce a multitude of various insults to the brain. Depending upon the location of primary and secondary injuries imposed on the brain, various motor control complications may result. The purpose of this chapter is to provide an overview of motor control impairments with which the patient with a TBI may present. Motor control assessments, treatment planning, and treatment implementation will be discussed in this chapter in an effort to assist the physical therapist in providing quality care for the TBI patient during trauma rehabilitation.

Evaluation of the TBI Patient

The physical therapist's evaluation of motor control will include three major components: musculoskeletal, muscle tone, and motor output. A musculoskeletal evaluation will include problems that are due to direct trauma or problems associated with secondary complications. A muscle tone evaluation will address abnormal resting tonus that may contribute to the development of musculoskeletal impairments, a motor output evaluation will accommodate reflexive and voluntary motor behaviors. In thoroughly evaluating the motor

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control components, the physical therapist may begin progressing toward the motor control-directed goal. This goal incorporates the prevention of musculoskeletal impairments which may result during the acute care of patients with TBI due to cognitive, motor, orthopedic, and medical/surgical restrictions preventing movement.5

Musculoskeletal Impairments.—Musculoskeletal impairments may be termed direct or indirect.28 One indirect impairment is abnormal joint alignment leading to pain, decreased movement, and decreased muscle length, all of which may ultimately result in decreased ROM. A second indirect impairment, tone, may lead to abnormal posturing and deformity. Heterotopic bone ossification is a third indirect impairment of the musculoskeletal system. Finally, general weakness, as an indirect impairment, may lead to muscle imbalances and abnormal posturing. Two direct musculoskeletal impairments include soft tissue impairments and orthopedic injuries.38 Gill-Body et al5 emphasized that when these common predictors of musculoskeletal impairments are identified, the physical therapist's intervention will result in improved musculoskeletal outcomes.

Muscle Tone.—The muscle tone evaluation is a method of identifying the resistance of a limb to quick passive movement. Muscle tone may be described as high, normal, or low tone. In treating tone, the physical therapist must be aware of factors such as motor control components, cognitive status, and the patient's overall medical management and be able to integrate them into the
treatment. For example, intercranial pressure is often associated with an implication of high muscle tone and, once ICP is stabilized, the patient's tone generally decreases.\(^5\)

**Motor Output.**—The motor output evaluation will assess reflexive and voluntary motor behaviors. Reflexive output is defined as "an obligatory response to peripheral stimulation."\(^5(p16)\) The therapist applies noxious stimuli such as a sternal rub, deep nail pressure or nipple pinching. Following the noxious stimulation, the therapist should note the following regarding reflexive movement: which extremity or part of the trunk moves, timing of the movement, range of the movement, quality of the movement, and return of the limb to resting position.\(^5\) It is crucial that therapists associate the intensity of the stimulus as equating the intensity of the motor output elicited. The therapist must use a consistent intensity with continued evaluation to ensure reliability of reflexive motor output assessment.

The physical therapist should also describe the patient's general posture as part of the motor output evaluation.\(^5\) Decorticate and decerebrate posturing are common reflexive movement patterns seen in patients with head injuries. Gill-Body et al\(^5\) described these postures as follows:

Decerebrate posturing produces marked extensor rigidity involving all extremities, occasionally head extension, adduction of the legs and pronation of the arms. In general, the arms are extended, although they may be
partially flexed. Decorticate posturing results in extension of the legs and marked flexion of the arms, wrists, and fingers with adduction of all four limbs. 

Acute flexor posture of the arms is a point of clinical difference between decorticate and decerebrate rigidity.\(^{(p16)}\)

Gill-Body continues, "... controversy exists as to whether these postures are constant or transient and what stimuli elicit the responses."\(^{(p16)}\) The decerebrate or decorticate posturing patterns may occur either continually or intermittently. In addition, sensory stimulation, either as part of the evaluation process or secondary to environmental conditions, may be the causal agent in the production of abnormal motor patterns. Abnormal patterns of motor output may stem from irritations within the body, which may be a complication secondary to the initial neural injury.\(^{5}\) The physical therapist must use caution when handling the patient to avoid soliciting the abnormal posturing.

Voluntary motor behavior, a second type of motor output, is defined as "postures and movement initiated by the person's own desire to act."\(^{(p17)}\) Voluntary motor behaviors may be conscious, carried out with deliberate attention and feedback, or automatic, carried out without conscious attention and under control by learned motor programs.

Conscious behavior may further be described as purposeful or non-purposeful.\(^{5}\) Purposeful movement is "self-initiated toward a target or
stimulus\(^{5(p17)}\) and is graded through manual muscle testing or a quality description. Gill-Body et al\(^5\) described important observations to be included in assessing a patient's conscious voluntary motor behaviors including: notation of constant, conscious motor behavior; ability to consistently perform conscious motor behavior from session to session; designation of specific limbs in which movement occurs; documentation of the range and speed in which movement takes place; and stimuli needed to facilitate a higher state of consciousness prior to voluntary movement practice.

In contrast, non-purposeful, unconscious, voluntary motor behavior is defined as "spontaneous movement with a goal or target."\(^{5(p17)}\) Only a quality description should be included in the notation of unconscious voluntary behavior.

Automatic voluntary movement should be observed during transitional movements, equilibrium testing, or other situations.\(^5\) Often, these opportunities do not occur during the intensive care management and rehabilitation for the TBI patient due to the severity of the acute condition. However, if it is possible to assess the response, notation should include where the movement occurred, the timing of the initiation of the movement, and the quality of the movement.

**Objectives**

Cherry\(^{39}\) stated, "A primary objective of physical therapy is maintaining or regaining range of motion in cases of orthopedic or neuromuscular dysfunction, in order to prevent or reduce myostatic contracture."\(^{5(p877)}\) Boughton et al\(^{32}\)
generalized the goal of the physical therapist, treating head injured patients in the ICU, to maintain or normalize motor skills necessary for function. Maintaining full ROM, preventing joint contractures, normalizing tone, and facilitating normal movement patterns are specific goals mentioned by Boughton.

Assessment of Motor Control

The physical therapist will frequently encounter ROM limitations in the brain injured patient due to increased muscle tone from CNS lesions or from unbalanced muscle groups. Flaccidity, low tone, may be just as prominent as spasticity, high tone. However, spastic muscle may lead to contracture development while flaccid muscles do not pose this risk. Therefore, the focus of this section regarding muscle tone will include only the treatment of spasticity and contracture prevention. It should be remembered, however, that a patient with flaccid muscle tone also requires passive range of motion two to three times per week to prevent joint capsule tightening and maintain range of motion. Contractures are defined by Cherry as a limitation of full ROM in the affected joint, with a resilience or springy end-feel, due to intrinsic muscle shortening. Contractures can affect any muscle, and causes of muscle contracture may include intrinsic adaptive changes in response to prolonged positioning, such as in orthopedic immobilization of the comatose patient. Poor positioning may result from a muscle shortening that is never lengthened by a weak opponent, resulting in a dynamic muscle imbalance. Finally, CNS damage may result in spasticity, which may lead to prolonged fixed posture and
possible contracture development. Contracture development may prevent the patient from receiving full rehabilitation later. Therefore, it is very important to prevent contractures from the start rather than correcting them later.  

**Treatment of Motor Control Complications**

Improvement of function is the general goal associated with spasticity. This may encompass patient-specific therapeutic goals since decreased spasticity will lead to improved positioning or sleep. These goals are considered in discerning treatment effectiveness and in determining whether to continue, stop, or change the treatment.

The treatment of motor control abnormalities, especially that of impaired muscle tone, encompasses a wide variety of techniques and modalities. In planning a treatment protocol, Mills indicated that the value of the muscle tone should be considered while evaluating it and that treatment should always be directed toward improvement of function, possibly with the use of the tone, as a priority, rather than decreasing abnormal signs or symptoms. A second consideration of treatment planning involves the appropriate incorporation of a specific treatment technique relative to the physiology of the spasticity. Cherry detailed these concepts in the following passage:

When tightness is caused by spasticity, the spastic muscle responds to stretch differently than does normal muscle. The spastic muscle or muscle group is characterized by exaggerated resistance to passive
stretch and, frequently, powerful reciprocal inhibition of its opponent. Tightness caused by spasticity and tightness of a normal muscle adaptively shortened because of plaster immobilization may require different modes of intervention. Treatment is more effective in preventing contractures from spasticity than it is in reducing [the contracture].

Cobble et al.\textsuperscript{11} recommended the following principles be followed when choosing a treatment method for spasticity. Use the minimal intervention with simple conservative measures necessary to achieve the therapeutic goal. Avoid use of measures that carry risk or side effects or that could impair the spared motor or sensory function or prohibit use of some future therapy.

Examples of techniques affecting muscle tone may include positioning, neurofacilatory or inhibitory techniques,\textsuperscript{5,22,32} early mobilization,\textsuperscript{18,22} various modalities,\textsuperscript{5,11} passive range of motion techniques,\textsuperscript{5} casting,\textsuperscript{5,16,18,32} phenol nerve blocks,\textsuperscript{11,16} medications and surgery.\textsuperscript{11} Physical therapists must thoroughly understand each of these techniques and be skillful in the application of the techniques performed within the physical therapist's professional realm. Each of these techniques will now be described.

\textbf{Positioning}.—Therapeutic positioning may be integrated into a treatment plan for many reasons. This discussion of positioning will refer only to positioning intended to reduce spasticity and prevent contracture development.
A comprehensive positioning program should involve bed positioning and total body positioning. Bed positioning integrates distinct positional changes (i.e., supine or sidelying) as well as preservation of good head, trunk and extremity alignment. Boughton et al\textsuperscript{34} discussed the separate bed positions and their implications with an emphasis on proximal and distal points of control to inhibit reflexive patterns as follows:

**Supine.**\textsuperscript{19}—The head of the patient's bed should be elevated 15° to 30° to control ICP. This position may be modified with a rolled towel under the knees to maintain knee flexion and support at the hips to limit rotation. To counteract extensor tonic labyrinthine positions, place both hips in extension, abduction, and external rotation; knees in flexion; and neutral ankles. Upper extremity components include full flexion, abduction and external rotation with the patient's hands behind his/her head. Boughton\textsuperscript{34} does not recommend the use of foot boards in supine because of the tendency to elicit positive supporting reaction to stimulate ankle clonus.

**One Quarter Turn to Sidelying.**\textsuperscript{19}—In this position, the weight of the patient's body is the point of proximal control for the bottom arm. The position includes bottom arm shoulder protraction, flexion, external rotation, elbow extension with neutral forearm position, and a relaxed hand (a reflex inhibiting posture).

**Three Quarter Turn to Prone.**\textsuperscript{19}—In this position, keep the upper arm in a reflexive inhibiting pattern described above with shoulder protraction, flexion,
external rotation, elbow extension with neutral forearm position, and a relaxed hand. This position incorporates trunk rotation by alternating lower extremity hip and knee flexion and extension while the ankle remains neutral between inversion and eversion.

*Prone.* Prone positioning is used to facilitate head control with optical and labyrinthine reflexes. It provides shoulder stability with weight bearing on elbows while stretching the hip flexors. The care provider can use bolsters or rolled sheets for support when the patient has tracheal tubes, ventilator support, or other lines and tubes.

Total body positioning utilizes the benefits of decreased total body tone through altered surface contacts, proprioceptive input, visual input, and vestibular stimulation. Specific positioning devices may augment segmental bed positioning strategies as described by Gill-Body et al. Some examples of the devices used to inhibit tone of the head, trunk, and limbs and to align joints include rolled sheets, sandbags, and full IV bags. Other suggestions include wedges for the head and shoulders, abductor wedges, reverse Trendelenberg positioning, portable tilt tables, or appropriate splints. Elevation of the bed to upright positioning is desired to increase visual, vestibular, and proprioceptive input. This will result in decreased muscle tone along with other benefits including increased environmental awareness, pressure changes on skin areas (which is further emphasized in a later portion of this paper), and increased lung expansion to facilitate pulmonary hygiene.
Gill-body et al\textsuperscript{6} and Boughton et al\textsuperscript{32} implicate early mobilization of even the most dependent TBI patient from the bed to the chair upon physician approval and appropriate medical stability. Good handling techniques, proper body mechanics, and maintenance of patient alignment is imperative during the transfer procedure. Special positioning devices used in the bed may also be used in the chair.

**Neurofacilitatory or Inhibitory Techniques.**—Cherry\textsuperscript{39} described four general approaches used to lengthen shortened muscles that may be prone to contracture. These approaches include activation or strengthening of the weak agonist, local inhibition of a strong antagonist, general inhibition of overall increased tone, and passive lengthening of shortened structures. In support of these techniques Kalisky et al\textsuperscript{6} stated:

If the antagonist is extremely weak or inhibited or both, facilitatory techniques may enhance its function and increase its strength, thereby enabling it to oppose the tight antagonist effectively. These techniques use exteroceptive and stimulation, causing summation in the CNS and lowers the threshold of efferent response or muscle action.\textsuperscript{(p879)}

**Activation or Strengthening of the Weak Agonist.**—The approach of activation or strengthening of the weak agonist incorporates three general treatment techniques.\textsuperscript{39} The first technique is resistance or load of the weak
agonist muscle which is unable to balance the dynamic actions of the opposing antagonist. Two methods described in this technique include maximal resistance in diagonal or spiral patterns, such as the diagonals used in Proprioceptive Neuromuscular Facilitation, or progressive resistive exercises. Often, the acute TBI patient is not an appropriate candidate for these techniques; however, the trauma physical therapist must be aware of their existence. A second technique used to strengthen weak agonists includes the use of unconscious automatic righting and equilibrium reactions. This technique is appropriate only for patients unable to respond appropriately to the treatment previously described. This method is the basis of the Brunnstrom technique. The third technique used to strengthen weak agonists incorporates various facilitatory techniques and is a part of the Rood approach to motor control. Specific skills described by Cherry and Hall et al. include vibration to the agonist, quick icing and brushing, tapping, EMG feedback, skilled manual contacts, traction, approximation, repeated contractions, and quick stretching. These applications are intended to facilitate contraction of the agonist muscle.

Local Inhibition of Strong Agonists.—The second major approach to lengthening shortened muscles is referred to as local inhibition of strong agonists. This approach is applicable to the agonist that is unable to contract or to an extremely tight muscle that cannot be lengthened. Also, the tight antagonist possesses a stretch reflex that must be inhibited in order for the
agonist to function fully. Cherry et al.\textsuperscript{39} attributed the following reasoning regarding specific local inhibition techniques:

Vibration to the opposing muscle group causes reciprocal inhibition to the contracted muscle. Neutral warmth causes decreased gamma motor neuron activity; prolonged icing causes slower nerve conduction and diminished spindle and myotatic reflex activity. The hold-relax and contract-relax techniques of proprioceptive neuromuscular facilitation work by means of successive induction, when a muscle is inhibited after a contraction while its opponent is facilitated. The hold-relax procedure has been found to be more effective than passive stretching in lengthening the hamstring muscles in normal individuals.\textsuperscript{(p879)}

\textit{General Inhibition of Spastic Tone.}—The third major approach to lengthening shortened muscles involves general inhibition of spastic tone throughout the patient's body.\textsuperscript{39} This approach may incorporate somatic and autonomic components of the CNS and is most effective when normal movement interference is attributed to hypertonicity or spasticity. Bobath and Rood both incorporate treatment techniques aimed at inhibiting spastic tone with a generalized approach. Treatment components of general inhibition include "key points of control" described by Bobath as movement patterns of proximal joints.
that affect the trunk and limbs. Cherry\textsuperscript{39} summarized the theory behind this approach, "When the spastic limb is inhibited, its muscles will not respond to stretch as readily, permitting the limb to move through more complete range of active motion and preventing the development of myostatic contractures."\textsuperscript{(p880)}

A specific treatment technique directed at general inhibition is slow, rhythmical rocking or rotation of the body around its axis.\textsuperscript{39} The slow rocking will decrease hypertonicity of the limbs and trunk and allow for increased freedom of movement. Slow rocking, said to provide low frequency vestibular stimulation and subsequent inhibition of the CNS reticular formation, leads to a calming effect.\textsuperscript{43} Though less relevant scientifically, slow rocking has an obvious calming effect on infants and children and has been used for ages to relax them.

Treating the patient on a slightly moving surface is another technique with two-fold rationalization described by Cherry.\textsuperscript{39} "The slightly moving surface is relaxing, probably like the effect of a rocking chair or other gently motion; and carefully graded and planned movement of the supporting surface requires subtle equilibrium responses as the patient adjusts to being moved."\textsuperscript{(p880)}

A final technique described by Cherry\textsuperscript{39} as effective in the general inhibition of tone is that of inverted positioning.\textsuperscript{36,43,44} According to Gellborn\textsuperscript{44} "increased blood pressure in the head stimulates the carotid sinus leading to a parasympathetic effect. If the patient can tolerate inversion, the resultant muscle relaxation may lead to the prevention of contracture development."\textsuperscript{(p880)} It is obvious,
however, that inverted positioning is contraindicated in the patient with unstable ICP or other abnormalities in hemodynamic status.

**Passive Lengthening.**—Passive lengthening is the fourth and final approach effective in lengthening shortened muscles.\(^{39}\) Passive lengthening must be used with caution because of the possibility of eliciting a stretch reflex when stretching the shortened muscles. Further, passive stretch may be painful and have limited effectiveness on the long term affects of prolonged immobilization. However, if the tight muscle is not responsive to the techniques described earlier, passive stretching may be indicated. By definition, passive stretch forces movement when ROM is decreased, due to decreased soft tissue elasticity. No motor learning is achieved through passive stretch because it is just that—passive.

Passive stretch is most effective when the stretch reflex is inhibited.\(^{39}\) Specifically, a stretch applied slowly may inhibit the reflex. Two approaches employ the concept of slow stretching to inhibit the stretch reflex. The first is prolonged positioning via fabricated orthoses and splints, adaptive equipment, or skilled positioning (described previously). A second approach to slow stretch is a manual passive stretch. This technique requires the skill of the therapist in discerning appropriate speed and duration of the stretch that is manually applied. The article by Cherry\(^{39}\) is an excellent resource regarding the treatment of motor control issues as it details the ideas presented in the preceding paragraphs.
Modalities.—Skilled and specific application of modalities such as ultrasound, hot/cold packs, biofeedback, electrical stimulation, and topical anesthetics have been described and used in the treatment of inhibiting abnormal tone and decreasing muscle contracture.\(^5\,21\,45\) Cryotherapy is one modality receiving increased attention as a temporary reducer of spasticity.\(^46\) Mitchlovitz\(^47\) maintained that despite an unknown mechanism responsible for this effect, many animal and human studies have been designed to clarify and provide rationale for the observed responses. Rappaport et al,\(^45\) in a study of humans, found that cryotherapy did reduce spasticity; however, the effects were inconsistent and of limited duration. Rappaport et al attributed the tactile stimulation associated with ice application as causing the “dichotomous results.” Rappaport indicated that cryotherapy may be useful prior to PROM techniques or stretching to further facilitate movement.

Heat as a modality, either via ultrasound, hot packs, or warm towels has been described as effective in decreasing tone.\(^47\) The neuromuscular principle that substantiates this is described by Mitchlovitz.\(^47\)

Heat is used therapeutically to provide analgesia and assist in resolution of muscle guarding spasm. Despite the unknown mechanism, heat has the ability to elevate the pain threshold, [making treatment more tolerable], alter nerve conduction velocity, and change muscle-spindle firing rates. Further, temporary temperature
elevation of skeletal muscle may temporarily change the
ability to build tension and sustain prolonged activity.\(^{(p38)}\)

**Passive Range of Motion Techniques.**—It should be emphasized that
passive ROM is simply movement of the various joints through their respective,
available ROM.\(^{38}\) Passive ROM exercises can serve to maintain the available
ROM provided by the adjacent muscle; however, it does not involve stretching
the involved musculature. Passive stretching techniques have been previously
described. Range of motion may also affect joint capsules and other non-elastic
components.

**Serial Casting.**—“Serial casting is repeated cast fabrication for the
purpose of ensuring a statically aligned joint position, stretching out
contractures, and preventing tightness and contractures.”\(^{16(p508)}\) Gill-Body et al\(^{5}\)
described serial casting as an extremely effective adjunct used in preventing
musculoskeletal impairments in the acute hospital setting. Booth et al\(^{48}\) also
supported serial casting and stated, “serial plaster casting is a technique that
has been used . . . to effectively manage spasticity-induced contractures or, in
the presence of potentially deforming spasticity, to prevent the development of
contractures.”\(^{n(p1960)}\) Booth further recommended “casting during acute and early
management so that immobilization occurs while the patient is at his lowest level
of consciousness.” Therefore, serial casting is used in acute care for the
purpose of contracture prevention, while later uses include deformity correction
and maximal alignment in anatomically normal positions to allow normal joint function.\textsuperscript{5,16,48}

Gill-Body et al\textsuperscript{5} described several factors related to the outcome of serial casting. These factors involve patient selection criteria, the type of cast applied, the type of material used in cast fabrication, duration of cast wear between changes, and adjunctive treatment used with cast wear. Conine et al,\textsuperscript{49} in an efficacy study regarding serial casting of the ankles, determined that the average gain in dorsiflexion range of motion was 21°, that their procedures were safe, and that their trial results were quite favorable.

Indications for serial casting include range of motion limitations due to soft tissue contracture resulting from spasticity.\textsuperscript{32,48} Serial casting has also been used in cases of heterotopic ossification, fractures, and ligamentous injuries, but not as effectively as in cases of spasticity. Medical stability is vital before consideration of the application of serial castings to avoid exacerbation of any existing conditions. The use of serial casting is implicated in the ICU in cases of increased muscle tone and extreme abnormal posturing.\textsuperscript{32}

A specific deformity often treated with serial casting is equinus deformity because of its occurrence with both decorticate and decerebrate posturing.\textsuperscript{48,49} Casting is preferred over manual stretching in treating equinus deformity because of decreased hyper-reflexia, stretched connective tissue effects associated with manual stretching, and the continued immobilization may facilitate the correction.
Contraindications to serial casting include orthopedic fixation and open fasciotomies, poor skin conditions due to lacerations or abrasions, and the need to access the extremities for other care provision procedures. Cognitive impairment may also contraindicate serial cast applications. Also, according to some authors, casting may cause and increase in the ICP. Therefore, an unstable medical status is a contraindication to cast application.

Conditions such as diabetes mellitus, peripheral vascular disease, open wounds, or impaired sensation require extra care regarding cast usage. Cast modifications, such as cut outs or padding, may allow for cast use in these situations. The toe box of all lower extremity casts is left open to allow observation of circulation. Cast cutters should always be available in the ICU for emergency removal of casts.

An example of patient selection criteria is described by Conine et al as follows: informed consent of the patient or custodian, Glasgow Coma Scale of less than 10 on admission, limit of the passive ankle dorsiflexion to 0° or less, the presence of "spasticity" in the involved lower extremity, and there must be no evidence of the generally accepted contraindications to casting as described previously. The reader is referred to the literature by the following authors for further information regarding serial casting application materials, methods, and procedures: Booth et al, Conine et al, and Davies.

A general protocol for serial cast application is discussed by several authors. The initial, resting cast is applied on the limb that is positioned at
the end of its comfortably available ROM and remains for 7 to 10\textsuperscript{48} or 7 to 14 days.\textsuperscript{32} Adequate joint position for cast application may be facilitated by the use of sedating or paralytic agents.\textsuperscript{32} Following the resting cast removal, positional, or drop-out, casts are applied at weekly intervals.\textsuperscript{48} Booth et al\textsuperscript{48} stated the average number of positional casts required is three to four before the maximum obtainable ROM is achieved and the application of the final ‘holding cast’ is deemed appropriate. The holding cast is used for approximately 7 to 10 days and is then converted to an anterior/posterior splint or bivalve cast for the patient to use approximately 18 hours per day, or just at night if necessary.\textsuperscript{49} Between cast changes, the limb is moved through its ROM and slightly further before application of the next cast. Permanent cast removal is appropriate upon discharge to a facility requesting removal or if ROM is greater than neutral for three successive casts.\textsuperscript{32}

**Pharmacological Intervention.**—Antispasticity medications may be used during the intensive care of the TBI patient.\textsuperscript{49} Many of the medications used for the treatment of patients with traumatic brain injury have been previously described in Chapter III.

The three most common drugs used for the reduction of spasticity include baclofen, diazepam, and dantrolene sodium.\textsuperscript{49} Baclofen and diazepam have central actions primarily at the spinal cord level “to enhance presynaptic inhibition” and are more effective at reducing spasticity due to SCI lesions. These two drugs may cause drowsiness and weakness that may affect the
physical therapist's assessment and treatment outcomes. Dantrolene sodium is effective peripherally, affecting the excitation-contraction coupling mechanism. These medications may have side effects affecting cognition and deter effective treatment. Generally, it is recommended to use a protocol of physical modalities before resorting to pharmacological intervention.

**Phenol Blocks.**—Mills\(^6\) described the use of phenol blocks to control spasticity of muscles. Phenol injections at motor points result in axon demyelination and subsequent decreased spasticity. Mills indicated that the use of phenol blocks is appropriate for all stages of recovery from TBI. The most important advantage of this procedure is its ability to eliminate spasticity and improve function.

**Surgery.**—Surgical procedures have been developed to improve patient function through the correction of deformities resulting from spasticity and resultant fixed contractures.\(^{11}\) Surgery is seldom used as a treatment technique for the TBI patient in the ICU suffering from spasticity because of the acute condition and the unlikelihood of permanent contracture formation in the short time the patient is treated acutely.

Common surgical procedures that may eventually be performed to treat spasticity not adequately controlled by conservative techniques are discussed by Cobble et al.\(^{11}\) The most common areas of surgical correction include the ankle to correct equinus, tenotomy of the long toe flexors, hamstring tendon release, posterior capsulotomies and iliotibial band release to correct knee
flexion contractures, adductor tenotomies, and obturator neuroectomy for hip
scissoring in gait.

The intention of this chapter was to provide an overview of common motor
ccontrol impairments encountered in the ICU during the treatment of the patient
with a TBI. By the use of thorough assessments and appropriate, skilled
treatment planning and implementation, the physical therapist shall be
competent and efficient regarding the care of motor control issues for the patient
with TBI.
CHAPTER V
HETEROTOPIC OSSIFICATION

Heterotopic ossification (HO) is a frequent complication in patients with severe head injury. Heterotopic ossification is defined as the "ectopic appearance of bone in soft tissues, paerarticular locations, primarily in proximal joints of the upper and lower extremities, and resulting in pain and decreased range of motion (ROM)." Bontke et al indicated that untreated HO may lead to major long-term disability including limited ROM and joint ankylosis, pain, spasticity, vascular and nerve compression, loss of muscle length, and lymphedema.

Risk factors for the development of HO include traumatic and vascular brain injuries with spasticity, prolonged coma for more than two weeks, and long bone fractures. Heterotopic ossification is reported as "an area of increased uptake on a bone scan and the degree of uptake depends on blood flow and osteoblastic active uptake may be seen in the growth plate regions and is considered normal in a growing skeleton." Therefore, it is imperative to compare bone scans of bilateral joints if possible to accurately evaluate growth-plate activity. The incidence of HO had been reported as 11% to 76% by Bontke et al in 1991. The incidence among children is reported at 3% in 1975 by
Hoffer and Brink\textsuperscript{51} to as high as 15\% in 1987 by Mital\textsuperscript{62} when HO is associated with acquired intracranial lesions and resultant cerebrospasticity.

Locations for the HO bone formation can include any joint of the body. Garland et al\textsuperscript{53} indicated that the affected joint is most commonly found in the limb affected by spasticity. Pidock,\textsuperscript{54} however, reported HO may occur in flaccid or spastic joints. The hip is most commonly affected by HO, followed, without ordered significance, by the elbows, knees, shoulder, ribs, metacarpal phalangeal, and interphalangeal joints.\textsuperscript{5,50,54,55}

**Diagnosis**

Accurate diagnosis is essential to providing appropriate care for the TBI patient with HO.\textsuperscript{54} Diagnosis of HO most commonly occurs through the identification of common clinical signs and symptoms. Heterotopic ossification may be associated with acute inflammatory-like symptoms, such as warmth, sudden onset of swelling due to increased synovial fluid around the joint, pain, or decreased ROM.\textsuperscript{15,50,53,54,56} Local signs and symptoms may also be associated with systemic symptoms, leading to HO often being mistaken initially as a deep vein thrombosis or urinary tract infection.\textsuperscript{56} Decreased range of motion may have serious implications regarding functional activities including dressing, sitting, transfers, perineal care, and ambulation. It is reported that of head injured adults with HO-affected joints, 16\% will have joints that become ankylosed and adjacent bones may become osteoporotic.\textsuperscript{54} This may lead to a
limited ability to perform functional activities and may ultimately prolong the rehabilitation process and lead to increased costs.

Confirmation of a diagnosis of HO may be achieved through a plane film x-ray or bone scans. Unfortunately, x-rays do not depict an affected joint until one to three weeks following the onset of symptoms. Bone scans offer the advantage of sensitivity and early diagnosis (3-6 weeks before the condition is visible on an x-ray), but at a significant cost. A more accurate method of diagnosis is to monitor the levels of serum alkaline phosphates (SAP) in the blood. Serum alkaline phosphates become elevated in the blood during osteoblastic and osteogenic activity associated with increased deposition of bone. Serum alkaline phosphates will be elevated during the acute and active phase of bone formation and returns to normal once the progression has stopped. Citra-Pietrolungo et al reports SAP levels may be increased up to seven weeks before clinical signs and symptoms of HO appear. Caution must be exercised when using SAP as a diagnostic tool, however, as the levels may be increased in association with fracture healing. Further, increased SAP levels do not identify the specific joint affected by HO.

Prevention

The cause of HO is unknown; therefore, the prevention of HO poses a great challenge. Because of the delayed onset of HO following a TBI, awareness and prevention of the condition is a crucial objective during the acute care phase. Although there is no known method for prevention of HO,
pharmacological intervention has proven effective in the delay of HO formation.\textsuperscript{54} Diphosphonates (disodium etidronate) or Diadronal is used to delay the mineralization process of bone formation.\textsuperscript{50,58,59} Indomethacin, a non-steroidal medication, may be used prophylactically.\textsuperscript{50} Salicylates have also been used prophylactically to prevent recurrence of HO formation following a surgical excision of existing HO bone.\textsuperscript{52}

Cautious physical therapy may also play a role in the attempt to prevent HO. Inappropriate physical therapy treatment has been suggested as a cause of HO due to the repetitive trauma that may be involved in therapy.\textsuperscript{54} Diaruf\textsuperscript{59} stated the appropriate level of aggressiveness of the ranging exercises and mobility training should be challenged. Aggressive ROM may be a form of microtrauma, causing bleeding to the area or triggering inflammatory changes in the soft tissue growth. The physical therapist must have knowledge of the appropriate skill and techniques for treating the HO-susceptible patient.

Davies\textsuperscript{42} described four treatment considerations the physical therapist should acknowledge in trying to prevent HO. These treatment considerations are positioning, turning, assistance with nursing procedures, and passive movements of the limbs.

**Positioning.**—Regular repositioning should aid in the reduction of spasticity and lower the risk of HO development.\textsuperscript{42} Prone positioning should be attempted as soon as possible to decrease hip flexion contractures. Forcing the patient into a particular position should be avoided and flexed limbs should be
allowed to relax independently, if necessary. Further positioning adjustment may be made as the patient relaxes.

**Turning.**—The optimal turning interval of the patient is every two hours. Two or more people should assist with the turn to avoid excessive trauma to the limbs. The patient’s limb should be flexed prior to the turn to allow shorter lever arms. Following the turn, the limbs may then be repositioned in a relaxed form. These principles apply when transferring the patient to/from bed as well.

**Assisting with Nursing Procedures.**—Several cares provided by nursing may require specific positioning of the patient. For example, an arm may need to be straight to facilitate accurate blood pressure measurement or the patient’s legs must be abducted to facilitate perineal hygiene. The therapist may assist nursing with these procedures by providing relaxation interventions to the involved area. This may assist in avoiding undo trauma and the subsequent prevention of HO formation.

**Passive Movements of the Limbs.**—Excessive force used in ROM procedures may cause increased trauma and lead to HO formation. The physical therapist is reminded to not force a limb into a range, but rather use extreme caution through a limited ROM. Further caution must be used in treating children to avoid damaging fragile growth plates. Hips, knees, and shoulders of pediatric and high risk patients should only be moved to 90° flexion. Full dorsiflexion of the foot, however, does not appear to be harmful. Davies offered further general recommendations. First, the proximal lever arm
should be used for passive movements rather than lifting the limb by the distal extremity. An example of this technique would be to assist the patient with a forward trunk lean in long-sitting in lieu of repetitive straight-leg-raising. Second, moving a patient’s limb after serial casting must be approached with extreme caution. Until the diagnoses of edema and inflammation have disappeared, passive flexion movements should be avoided.

**Treatment**

Following the diagnosis of HO, a few treatment procedures have been described to prevent further deterioration and HO implication.\(^24,52-54,60\) Serial casting to prevent further deformity has been described in Chapter IV. Various medications used for the prevention of HO, such as Disodium etidronate, nonsteroidal anti-inflammatories, or salycilates, are also indicated to decrease the progression of HO following its detection.\(^15,50\) Finally, the physical therapist may utilize techniques such as those described in Chapter IV to gain control over spasticity. The therapist should also design positioning programs intended to obtain the most functional position of the joint should ankylosis set in.

Severely limiting HO may be an indication for the excision of the ectopic bone.\(^59\) Surgery may be performed to remove the function limiting bone upon full maturation of the HO and surgery will provide for increased ROM. The risk of regrowth appears to be minimal, especially in the elbows. \(^59\) recommended soft tissue treatment following surgical excision of HO bone
regrowth. The physical therapist should be aware of these procedures, even though they will not occur in the intensive care provision, for a patient with TBI.

Lithotripters may also be beneficial in the treatment of HO. Lithotripsy is a technique used to treat gallstones. In treating HO, the bony deposit is crushed by the use of electric waves transmitted through water toward the patient’s affected joint. The benefits of this procedure include an epidural anesthesia and a shorter recovery period following the procedure. The use of lithotripters in the treatment of HO is not standard practice, however, and research and appropriate scientific studies are indicated.

Therapist knowledge of HO as a complication following TBI will enable the provision of the most effective care possible. The therapist must become proficient in the skill required for treatment of the TBI patient subject to HO formation. Therapists must consider all the indications and contraindications for any procedure applied, in providing trauma rehabilitation for the severely head injured patient.
CHAPTER VI

SKIN CARE

The skin, made up of cutaneous membranes, is considered the largest organ of the body.\textsuperscript{61} It is composed of the epidermis as an outer layer and the dermis or inner layer. A few of the skin's major functions include: protection, thermoregulation, secretion, and sensation. Specific receptors in the skin are sensitive to pain, temperature, touch, and pressure. The brain, upon receiving information regarding the sensations from respective receptors, is responsible for interpreting the information appropriately. When the brain is insulted from a TBI, these sensations may be interpreted inappropriately or not interpreted at all. Poor or absent perception of these sensations may lead to increased risk for skin breakdown. This risk is made even greater due to the patient's inability to move appropriately and independently or inability to communicate his/her need to be moved. Generally, skin breakdown prevention is the responsibility of nursing staff; however, the physical therapist may make specific recommendations regarding positioning, special beds, cushions, or splints to help prevent skin breakdown. Also, physical therapists mobilize the patient as early as possible to decrease the potential for complications, including skin breakdown.\textsuperscript{19}
Skin breakdown may involve many different causes and various symptom presentations. For example, prolonged posturing and spasticity may lead to decubitus ulcers and/or bacterial or fungal infections. Other causes of skin conditions in the TBI patient might include reactions to medications such as antibiotics and anticonvulsants. Horn et al refers to eight skin conditions the TBI patient may develop including pressure sores, sweat disorders, drug reactions, acne, seborrhea, infections, swelling (edema), and cosmetic deformity. The physical therapist should be aware of the possibility of these complications in order to provide comprehensive, competent care for the TBI patient. This chapter will focus on the measures a physical therapist can take to prevent and treat skin breakdown during the trauma rehabilitation of the patient with TBI.

Skin breakdown may be due to either intrinsic or extrinsic factors or a combination of both. Extrinsic factors include pressure against areas of skin during prolonged lying or sitting, injury to the skin, wrinkled clothes or sheets, or too tight casts or medical accessories. Intrinsic factors may include edema, decrease ROM, loss of muscle function, decreased sensation, or poor nutrition. The combined effect of intrinsic and extrinsic factors results in the following list of risks associated with skin breakdown and decubitus ulcer formation: unrelieved pressure, moisture, nutritional depletion, decreased activity or immobility, and altered mental status. The patient with TBI is subject to many, if not all, of these risk factors and is at a substantial risk for skin breakdown.
Unrelieved Pressure.—A direct relation between skin necrosis and the amount and duration of pressure has been shown. Dr. Michael Kosiak, from the University of Minnesota, demonstrated the possibility of pressure sores induction after 90 minutes of intense pressure or by eight hours of less intense pressure as well as direct relationship between pressure and the onset of the actual sore. Kosiak reported that skin breakdown will not necessarily appear immediately after pressure, but could possibly take five days for the development of tissue breakdown. Initially, the skin may demonstrates a persistent redness, while it may look normal by the next day. However, within five days, it starts to break down. Upon pressure relief and prevention of infection, granulation and scar tissue will fill in the ulcer crater, and skin will finally grow over it after weeks or months. This new skin is more susceptible to future breakdown, implicating the body’s first line of defense, the integumentary system, is weakened.

Common locations for decubitus ulcer formation are over bony prominences, such as the sacrum, heels, trochanters, lateral malleoli, and ischial tuberosity areas. The blood supply to the affected areas will be restricted due to the pressure, which may result in ischemic tissue death affecting the associated skin, muscle, and bone.

Interventions the physical therapist may provide to prevent pressure sores include incorporation of a turning program and suggestion of pressure relieving devices. Turning the patient every two hours (or more often for the high
risk patient) is recommended by several authors.\textsuperscript{61,63} Many various positioning procedures are applicable to the patient with a TBI being treated in the ICU. The physical therapist must initiate a positioning program which incorporates all of the components of care for the patient, including positioning to control muscle tone as described in Chapter IV, along with positioning to prevent skin breakdown.

Three positions will be discussed in regard to the prevention of skin breakdown. These positions include supine, prone, and sidelying. In supine, the physical therapist must assure that the shoulders are parallel to the hips and the spine is straight.\textsuperscript{34,61} A pillow should be placed under the back to relieve low-back strain, and a second pillow under the knees will allow the heels to be raised from the bed and free of pressure. The therapist should also watch that the feet are not forced into dorsiflexion by bed linens that are tucked in too tightly.

Prone positioning to prevent skin breakdown includes turning of the patient’s head to one side (avoiding pressure on the eyes, nose, and mouth) or placing a small towel roll or pillow under the patient’s forehead while leaving the neck in midline.\textsuperscript{64} The shoulders will be parallel to the hips and the spine straight. The patient’s arms must be slightly abducted and in neutral at the patient’s side. A pillow should be placed under the patient’s trunk and low back to avoid cervical and lumbar strain. To avoid excessive plantarflexion of the feet, a pillow may be placed under the lower legs, or the feet may be placed over
the end of the bed to avoid excessive knee flexion. Often prone positioning in the ICU is contraindicated due to various medical interventions and secondary injuries the patient may have.

In sidelying, the therapist must avoid excessive pressure over the patient's bony prominences and pay attention to spinal alignment. A pillow should be placed under the patient's head to provide good neck alignment. More pillows are placed proximally and distally to the patient's greater trochanter to bridge the bony prominence. The proximal pillow should be above the patient's lower iliac crest to allow good lumbar and thoracic spinal alignment. The patient's trunk should be rotated slightly to bring the bottom arm forward and allow the patient to rest on the scapula rather than the tuberosity of the humerus. In sidelying, patients may be inclined forward with support provided by a pillow placed anteriorly, or they may be inclined backward with a posteriorly placed pillow for support. The upper extremity on top may be placed on the supportive pillow in front or behind the patient. Finally, a pillow should be placed between the patient's legs, which are slightly flexed at the hips and knees. The top leg should be slightly anterior or posterior to the bottom leg to avoid excessive weight on the bottom leg. Before the therapist should attempt any of these positions, it should be confirmed that the position is not contraindicated by medical devices or the severity and extent of the patient's injuries.

Pressure relieving devices the therapist may use may be as simple as a sheepskin, pillows, and rolled towels or as complex as specialized mattresses.
and beds. In choosing special mattresses, the therapist must consider the patient's needs as well as cost and appropriateness of the equipment.

Other options for pressure relieving devices may include foam mattresses, gel pads, water mattresses, alternating pressure pads, or suspension systems. Foam mattresses, available in various thickness, have the advantages of easy obtainability, a wide range of prices and quality, portability, and adaptability to most beds and chairs. Foam mattresses may be used to provide comfort, reduce shear, and equalize pressure. Disadvantages of foam mattresses include the increased moisture buildup and the tendency for the foam to crush. Further, foam is destroyed by incontinence, retains heat, and is not reimbursable by many insurance companies.

Gel padding, used to reduce shear forces, is advantageous due to good support and durability. Disadvantages of gel pads are increased weight of the pad, heat, and the need for the pad to be placed in a special foam mattress.

Water mattresses are most beneficial for reducing pressure. They are advantageous in their excellent pressure quality and/or the ability to control their temperature. Disadvantages of the water mattress include not allowing elevation of the head of the bed, difficulties encountered when transferring a patient in or out of bed, the requirement of special sheets, and an increase in shearing forces with movement.

Alternating pressure pads, which are tubes of air or water that inflate or deflate at intervals, are use to reduce pressure. Advantages of alternating pads include...
pressure pads include easy obtainability, a wide range of quality and price, portability, and the ability to use regular sheets. Disadvantages include noisy pumps and the risk of puncturing the mattress.

Suspension systems, which provide support similar to floating on air, use silicone beads or air pillows to support the body. These systems are used to provide comfort, reduce shear, and reduce pressure. Advantages of suspension systems include excellent pressure equalization and temperature control. Disadvantages include expense (usually they are leased or rented), inability to elevate the head of the bed with some models, bulky apparatus, excessive use of power, and the requirement of staff orientation.

**Moisture.**—Moisture does not decrease skin circulation, but softens collagen fibers and contributes to skin breakdown. Increased moisture may be due to perspiration, incontinence, and the increased heat and moisture buildup resulting from positioning devices. The physical therapist must assist in garment or linen changes to aid in minimizing the risks of skin breakdown associated with moisture. Further, the physical therapist may provide relaxation techniques to promote positioning that is advantageous for hygiene cares for the TBI patient.

**Nutritional Depletion.**—The patient's nutritional status affects his/her ability to heal once a decubitus ulcer has formed. The dietitian's role is very important in suggesting adequate nutrition for the patient to promote healing from TBI, skin breakdown, and other secondary complications of TBI.
Decreased Mobility or Immobility.—The TBI patient requiring ICU and trauma care provisions will generally suffer from decreased mobility or immobility.\textsuperscript{61} The patient may also be unable to communicate his/her needs to move or change position. Therefore, positioning suggestions and motor control issues discussed in Chapter IV are, again, relevant.

Altered Mental Status.—The patient’s mental status, emotional status, and cognitive functioning level will have a direct effect on posturing, type of movement, and ability to participate in positioning programs.\textsuperscript{61} The physical therapist must acknowledge his/her patient’s mental functioning and cognitive status when establishing goals and forming treatment plans regarding positioning to provide complete care for the TBI patient.

Assessment And Treatment

The physical therapist should perform an adequate skin inspection before, during, and after each treatment session.\textsuperscript{5} Observation should include color, temperature, and presence or absence of lesions. Areas indicating possible breakdown should be noted appropriately and communicated to the nursing staff.

When assessing the severity of skin breakdown, it is beneficial to use a standardized scale in describing the decubitus ulcer or potential ulcer.\textsuperscript{5} The Merk Manual\textsuperscript{63} provides such a scale by using six separate levels. These levels are described in Table 7.
Table 7.— Levels of Decubitus Ulcer Formation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reactive hyperemia, blanchable erythema. Skin redness that blanches with pressure. The skin and soft tissues are soft and may feel edematous and warm.</td>
</tr>
<tr>
<td>2</td>
<td>Non-blanchable erythema. Red edematous appearance with possible epidermal blistering. The area may be painful and cool to the touch.</td>
</tr>
<tr>
<td>3</td>
<td>Necrotic skin with fat exposure and wound drainage</td>
</tr>
<tr>
<td>4</td>
<td>Necrotic skin, fat, and muscle</td>
</tr>
<tr>
<td>5</td>
<td>More tissue involvement along with necrosis of fat and muscle</td>
</tr>
<tr>
<td>6</td>
<td>Destruction of bone</td>
</tr>
</tbody>
</table>
Treatment of pressure sores may be as simple as maintaining circulation by removing the pressure or repositioning the patient.\textsuperscript{63} Stage three ulcers and below may heal spontaneously. The physical therapist may be involved in debridement of the wound if the pressure ulcer has reached a stage four or beyond. Many different topical applications, gels, and dressings are used in the treatment of pressure sores. A discussion of appropriate dressings and debridement procedures is beyond the scope of this paper. Physical therapists should take responsibility in educating themselves and the rehabilitation team regarding appropriate dressings and procedures as necessary.

The physical therapist, as a member of the trauma rehabilitation team treating a TBI patient, plays a vital role in the care of the patient’s skin. While many treatment techniques exist to promote the healing of decubitus ulcers, prevention is the most important treatment tool the physical therapist has when treating the patient with a TBI.\textsuperscript{19}
CHAPTER VII

INJURY SEVERITY AND OUTCOME MEASURES

Many standardized tools have been devised to allow the rehabilitation team to understand the condition of their patient, to appropriately plan treatment regimes, and to facilitate communication between members of the team. Often, outcome is measured grossly by categorizing it in terms of mortality or morbidity. "Mortality is an all-or-none phenomenon; but morbidity is a graded response to injury and its medical treatment, varying from complete return to normality at one end of the scale, to total dependence on other people, requiring residence in an institution at the other end.\textsuperscript{20(p527)} There is a need for a more precise classification system to define the graded responses to injury involved with morbidity. "Predicting survivors' outcomes from severe brain injury is a prerequisite for planning treatment, providing realistic prognoses for families, and making decisions about long-term care and rehabilitation.\textsuperscript{23(p320)} Several systems have been developed to meet this need. Only a few, however, are
appropriate for use during the trauma rehabilitation of the TBI patient being treated in the ICU.

The purpose of this chapter is to describe a select few of the injury severity and outcome assessment tools appropriate for use in the ICU. It is beyond the scope of this paper to compare and contrast the selected assessment tools and defend their reliability and validity. Instead, scales will be described only to provide a general introduction and understanding about the scales for the reader. The tools that will be discussed include the Glasgow Coma Scale, the Ranchos Los Amigos Levels of Cognitive Functioning Scale, the Functional Independence Measure, and the Disability Rating Scale. The trauma rehabilitation physical therapist is encouraged to pursue further knowledge regarding these assessment tools as necessary.

Glasgow Coma Scale (GCS)

The earliest signs of neurological improvement decline may be measured by changes in the level of consciousness. The GCS is an injury severity scale designed to measure levels of consciousness and is the most widely used scale to assess injury severity during the acute stage. The GCS bases its prognostic indications on the premise that the degree and duration of coma reflects the severity of diffuse injury. The GCS is indicated by a need to assess consciousness, rate injury severity, and monitor recovery. It may be administered several times a day with reliability and consistency if administrators are trained well.
The GCS score is a summary score ranging from 3 to 15, composed of three component ratings which include eye opening, best motor response, and verbal response. The minimum score is 3, while a maximum score of 15 indicates complete recovery from brain injury. A patient scoring eight or greater is in a coma and has sustained a severe brain injury. This patient has a less than favorable prognosis if this score is maintained for more than 72 hours following injury. Table 8 depicts the GCS categories, levels of response, and the appropriate score for each level.

The procedure for administering the GCS consists of various attempts to elicit responses in the three categories of eye opening, verbal, and motor response. Gill-Body et al. describes the procedure:

[D]uring evaluation, the best response is recorded for each area. When a GCS assessment is being performed, responses in each category to voluntary requests score higher than responses elicited by noxious stimuli. If there is no response to the command, the therapist may apply a noxious stimulus, such as deep nail bed pressure onto the hallux, and elicit a flexor withdrawal response. A similar noxious stimulus is used to elicit responses in the other two categories (eye opening and verbal response). When a noxious stimulus is used to attempt to elicit a
### Table 8.— Glasgow Coma Scale Responsiveness Levels and Scores*

<table>
<thead>
<tr>
<th>EYE OPENING</th>
<th>BEST MOTOR RESPONSE</th>
<th>VERBAL RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>Description</td>
<td>Score</td>
</tr>
<tr>
<td>4</td>
<td>Spontaneous</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>To speech</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>To pain</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>No response</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

*Total score may range from 3 to 15.

*Adapted from Jennett and Teasdale\(^{65}\)
response, the intensity of that stimulus may influence the reliability of the patient's response. Therefore, practice and consistency in applying noxious stimuli to patients is imperative.\textsuperscript{(pp10-11)}

A general depiction of the prognostic benefit of the GCS is provided by Uotmo et al.\textsuperscript{66}

An increase in mortality occurs as the GCS score deteriorates. Of all patients whose admission GCS is 9 or better, 75-100\% will survive their injury with satisfactory outcomes, while 75-98\% of patients whose admission GCS score is less than 9 will not survive. The mortality rate reaches 90-100\% as admission GCS scores deteriorate to less than 5.\textsuperscript{(p63)}

Spettell et al.\textsuperscript{23} indicated that the GCS may not be an effective scale when applied as a summary score. Spettel's reasoning is that one of the three categories may not be testable (i.e., verbal response unable to be assessed due to intubation or an ocular injury precluding assessment of eye opening response) and thus misrepresents the patient on the scale. Spettell goes on to cite Eaisenberg and Winer\textsuperscript{67} who conclude that "motor score, alone, is the major determinant of outcome, and has only slightly less predictive power than the sum score of the GCS."\textsuperscript{321}
The appropriate time for administration of the GCS is argued by Miller et al.\textsuperscript{68} Miller stated that initial administration of the GCS sooner than six hours post-injury may weaken prognostic correlations because the patient may not be fully resuscitated yet. However, administration after six hours post-injury may be complicated by the presence of endotracheal tubes or the administration of muscle relaxants or anaesthetics.\textsuperscript{68} When the ICU physical therapist is applying the GCS score in evaluation and treatment planning procedures, these factors must be considered.

**Ranchos Los Amigos Levels of Cognitive Functioning Scale**

The Ranchos Los Amigos Levels of Cognitive Functioning Scale (RLA LOC or LOC scale) is based on descriptions of levels of cognitive functioning and the progression of the patient through these levels to describe recovery.\textsuperscript{69} Specifically, the LOC scale provides a description of the relationship between cognition and behavior, identifies phases of cognitive behavioral recovery after brain injury, and can be used to develop strategies for promoting recovery.

The RLA LOC Scale is described as a “range from no response to any stimulus to purposeful and appropriate behavior.”\textsuperscript{5} The procedure for administration is described by Gill-Body et al.\textsuperscript{5}

The level of cognitive functioning is determined by patient observation across time under the following conditions: in various environments, at different times of the day, with graded stimuli, without manipulation of
the environmental stimuli, and with and without
integration of physical activity. A dominant level (rated
from I to VIII) best describing the patient's behavior
becomes apparent. A patient may also exhibit
behaviors in two adjacent levels and hence be
described in a range of levels.\(^{12}\)

Table 9 provides a description of each of the 8 levels used to define the
cognitive functioning of the TBI patient.

Because of the limitations of both the GCS and the RLA LOC Scale, Gill-
Body et al\(^5\) recommended the combined use of both scales to provide the most
complete assessment of the TBI patient in the ICU. "Caution must be taken to
integrate other factors that may affect cognition, such as sedation level by
chemical means, sleep deprivation, metabolic imbalances, and hyperthermic
state."\(^{13}\) Table 10 provides a comparison of the scores obtained from the
GCS versus the LOC level. This comparison of scores implies increased
sensitivity of the GCS in monitoring neurological changes in the comatose TBI
patient, whereas the LOC Scale provides a more appropriate description as the
patient emerges from the coma. Again, the physical therapist must make
appropriate considerations when applying the score obtained from each
assessment and the application of those scores toward evaluation and treatment
planning.
Table 9.— Ranchos Los Amigos Levels of Cognitive Functioning.*

<table>
<thead>
<tr>
<th>COGNITIVE FUNCTIONING LEVEL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.  No Response</td>
<td>Patient unresponsive to any stimuli</td>
</tr>
<tr>
<td>II. Generalized Response</td>
<td>Inconsistent and nonpurposeful reaction to stimuli that are limited and do not vary with type of stimuli. Physiological change, gross body movement, and vocalization are examples of reactions.</td>
</tr>
<tr>
<td>III. Localized Response</td>
<td>Specific, inconsistent reaction, directly related to stimuli type. Inconsistent, delayed following of simple commands</td>
</tr>
<tr>
<td>IV. Confused-Agitated</td>
<td>Patient in an increased activity state, with strange and nonpurposeful environmental relations. Incoherent verbalization and inappropriate interaction with treatment.</td>
</tr>
<tr>
<td>IV. Confused, Inappropriate</td>
<td>Consistent response to simple commands, with gross environmental attention. Appears functionally automatic in a structured environment</td>
</tr>
<tr>
<td>VI. Confused-Appropriate</td>
<td>Goal-directed behavior if facilitated by external input, with consistent following of simple commands. Demonstrates carry-over learning. Impaired judgment.</td>
</tr>
<tr>
<td>VII. Automatic-Appropriate</td>
<td>Appropriate and oriented in structure environment, with shallow activity recall. Able to initiate activities.</td>
</tr>
<tr>
<td>VIII. Purposeful and Appropriate</td>
<td>Aware and responsive to environment with recall and integration of recent events. No longer requires supervision for learned activities. Maintains decreased ability compared to premorbid function.</td>
</tr>
</tbody>
</table>

Adapted from Gill-Body et al."
Table 10.— Comparison of Glasgow Coma Scale (GCS) Scores and Ranchos Los Amigos Levels of Cognitive Functioning (LOC) Scores.*

<table>
<thead>
<tr>
<th>Glasgow Coma Scale</th>
<th>Levels of Cognitive Functioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>I</td>
</tr>
<tr>
<td>4 to 8</td>
<td>II</td>
</tr>
<tr>
<td>9 to 15</td>
<td>III to VI</td>
</tr>
</tbody>
</table>

*Adapted from Gill-Body et al"
Functional Independence Measure

The Functional Independence Measure (FIM) is used to assess TBI patient’s function in terms of the level of assistance the patient needs for the completion of functional tasks. Generally, the FIM is used throughout a patient’s rehabilitation to assess the progress of the rehabilitation program. Hetherington et al. found that the FIM may also be used appropriately to measure disability in trauma victims. Advantages of using the FIM in the ICU are that all patients can be assessed regardless of diagnosis, it is repeatable in an acute hospital setting and at subsequent follow-up interviews in different environments, the average time to complete the form is 10 minutes, it is easily reproducible, it is efficient, it is acceptable to ill patients, and it does not interfere with treatment. Hetherington et al. indicated that the FIM should be administered within three days of admission. Use of the FIM is disadvantageous for the multidisciplinary team in the ICU however, in that “it appears to measure physical disabilities better than cognitive, language, and behavioral changes commonly seen following a TBI.” For this reason, a Functional Assessment Measure, or FAM, is being designed by the TBI Model Systems Program of the National Institute for Disability and Rehabilitation Research to integrate language, cognition, and behavioral functioning.

The procedure for administration of the FIM is described by Hetherington et al. as follows: “FIM consists of 18 separate items and is divided into six sections as follows: self care, sphincter control, mobility, locomotion,
communication, and social cognition. Each item is separately graded according to a seven-point scale, with one equaling total dependence and seven equaling full independence. The scoring range for FIM is from 18 (dependence) to 126 (fully independent). *(p97)  

**Disability Rating Scale**

The Disability Rating Scale (DRS) was developed by Rappaport et al.\(^2\) as "an instrument for assessing qualitatively the disability of severe head trauma patients so their rehabilitative progress may be followed from coma through different levels of awareness and functioning to their return to the community."\(^{118}\) The DRS is a useful tool for the trauma rehabilitation physical therapist in that it provides a tool to enhance the referral process for patients once they can be discharged from acute care. Benefits of the DRS, as described by the creators, include easy learning and application of the test, a quick assessment time, validity, and high interrater reliability when used to predict outcomes.\(^2\) Rappaport et al\(^2\) also proposed that the DRS will be more sensitive to assessing changes clinically in patients with TBI than the GCS. The procedure for administering the DRS involves assessment of eight items within four categories. The four categories are: arousability, awareness, and responsively; cognitive ability for self care activities; dependence on others; and psychosocial adaptability.\(^2\) These categories are described as follows:

**Arousability, Awareness, and Responsibility.**\(^2\) — This category, said to be a modified GCS, allows for the assignment of numerical values for eye
opening, verbalization, and motor response. In the DRS scale, the scores are inverted when compared to the GCS, allowing for a measure of the degree of impairment rather than a measure of wellness. For example, a high GCS score indicates a favorable condition, while a high DRS score is relative to a highly impaired patient.

**Cognitive Ability for Self Care Activities.**—This category measures the patient's cognition regarding feeding, toileting, and grooming. Rather than assessing the patient's physical ability to perform these functions, this portion of the DRS only measure the patient's knowledge of the appropriate time and procedure for performing these functions.

**Dependence on Others.**—This category measures the patient's level of functioning activity. The score may be graded from 0 which equals complete independence to 5 which equals total independence.

**Psychosocial Adaptability.**—This category assesses the employability of the patient, with scores encompassing non-restricted employability to non-employable. This category is applicable to the patient's potential to be an employee, student, or homemaker. Once the assessment of each category is complete, the administrator totals the score from each category and uses the sum to define the patient's overall level of disability, which ranges from "none" to "death."

In using the DRS as a prognostic indicator of outcomes from TBI, Rappaport emphasized the direct correlation between initial DRS scores and
one year post injury DRS scores. This provides support for the use of the DRS as a tool for the physical therapist in rehabilitation referral of TBI patients once they have achieved satisfactory recovery and can then be transferred from the acute care or ICU. The article, Disability Rating Scale for Severe Head Trauma: Coma to Community, (The Archives of Physical Medicine and Rehabilitation, 1982, v 63 pp 118-123),²¹ is an excellent resource for further clarification of the DRS scale.

Through experience and understanding of the injury severity and outcome measure tools described in this chapter, trauma rehabilitation physical therapists should become more competent and efficient in the evaluation, treatment, and subsequent re-assessments of the patient with TBI. This chapter does not encompass all measurement tools appropriate for use in the ICU. The physical therapist practicing in the ICU should make it a priority to thoroughly understand the specific tool used in their facility.
CHAPTER VIII

CONCLUSIONS

Traumatic brain injury has reached epidemic proportions in the United States. With decreasing mortality rates associated with TBI, rehabilitation providers are challenged to provide efficient, competent, and effective care to ensure that the patient has the opportunity to achieve the highest possible satisfactory level of function.

Recently, the initiation of rehabilitation immediately upon stabilization of the patient, following the TBI insult, has been termed trauma rehabilitation. Formalized trauma rehabilitation programs have been proven effective in decreasing primary-care-hospital and rehabilitation-hospital lengths of stay, and therefore decreasing the cost of care for the TBI victim. Further, formalized trauma rehabilitation programs appear to positively affect the TBI patient's functional outcome upon discharge from the primary care hospital and the rehabilitation hospital.

A formalized trauma rehabilitation program employs a multidisciplinary team, which functions to assist the patient to achieve general goals of survival from the injury as well as specific goals directed at maximizing functional outcomes. Physical therapists are important members of the
multidisciplinary trauma rehabilitation team. For some physical therapists, the role of rehabilitation in the ICU is a new concept. A thorough understanding by physical therapists of common medical equipment encountered in the ICU and physical therapy treatment implications specific to the ICU should assist them in providing competent evaluations and assessments and implementing effective treatment programs.

Prevention of secondary complications related to TBI and its subsequent prolonged immobilization is a common goal shared by all members of the multidisciplinary trauma rehabilitation team.\textsuperscript{2,19,21} A few specific secondary complications that may result from a TBI include neurologically induced musculoskeletal impairments, heterotopic ossification, and skin breakdown.\textsuperscript{19}

The use of standardized injury severity and outcome measures is beneficial to effectively treat the TBI patient and communicate with the multidisciplinary team.\textsuperscript{23} A brief discussion of a few selected measurement devices appropriate for the trauma patient are described to provide a general introduction and review for the reader. These devices include the Glasgow Coma Scale, the Ranchos Los Amigos Levels of Cognitive Functioning Scale, the Functional Independence Measure, and the Disability Rating Scale.

Future research is needed regarding the efficacy of physical therapy relative to trauma rehabilitation. It is more important, however, for physical therapists to acknowledge their need for further instruction about specific trauma rehabilitation evaluation, assessment, and treatment implications and
techniques. Physical therapists need to aggressively pursue further knowledge continuously to become competent, efficient, and effective in their provision of trauma rehabilitative care.
REFERENCES


43. Ayres AJ: *Sensory Integration and Learning Disorders*. Los Angeles, Calif: Western Psychological Services; 1972:120.


