Bed Mechanisms used in Spinal Cord Surgery: A Review

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Abstract— The spinal cord surgery requires a specific position of a patient. For this specific type of beds are required for operation purpose. The presently available surgical beds for spinal surgery are very costly starting from 2 lacks. The cost of the spinal cord surgery is also too high. Thus results in increasing hospital charges. Increasing cost of surgery and hospital charges is major problem now a day's which is very difficult to pay the charges for a common person. The aim of designer should be development of a cost efficient surgical bed of the spinal cord surgical attachment on the existing bed. This will help in reducing the cost of surgery and will be alternative to existing heavy spinal cord surgical bed. This paper aims to have a review of existing surgical bed, the mechanism used, etc. This review paper will helps the designer to provide information for the design and development of surgical bed which can serve as an alternative to the costly designs existing in the market. It will reduce the indirect cost of surgery and thus make it more affordable to the common man.

Key words: Human Spinal Cord, Vertebrate, Spinal Cord Injury (Sci)

I. INTRODUCTION

The human spinal cord consists of nerves that connect the brain to nerves in the body. It is a superhighway for messages between the brain and the rest of the body. The spinal cord is surrounded for most of its length by the bones (vertebrae) that form the spine. The human spinal cord, part of the central nervous system, is generally around 17 inches long, and extends from the brain to the lower back. Our spinal cord is protected by the vertebral column (also known as the spinal column or backbone). The human spinal column is made up of 33 bones - 7 vertebrae in the cervical region, 12 in the thoracic region, 5 in the lumbar region, 5 in the sacral region and 4 in the coccygeal region as shown in figure (1).

A spinal cord injury (SCI) is damage to the spinal cord that causes changes in its function, either temporary or permanent. These changes translate into loss of muscle function sensation, or automatic in parts of the body served by the spinal cord below the level of the lesion. Injuries can occur at any level of the spinal cord and can be classified as complete injury, a total loss of sensation and muscle function, or incomplete, meaning some nervous signals are able to travel past the injured area of the cord.

A spinal cord injury (SCI) is damage to any part of the spinal cord, the bundle of nerves that runs from the brain down the vertebral column, or disease. The injury can prevent motor signals from reaching the muscles, resulting in paralysis, or sensory information from reaching the brain

The ideal position for spinal surgery should facilitate exposure, minimize both bleeding and the likelihood of damage to vital structures, and allows proper ventilation of the anesthetized patient. Additionally, it is imperative to avoid any postoperative morbidity secondary to the position during surgery.

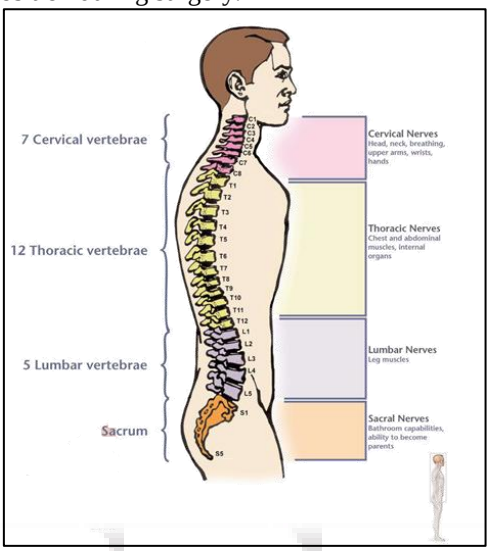

Fig. 1: Human spinal cord

These goals are more important, or potentially more difficult to achieve, in spinal surgery because of the deep exposures, and occasionally related difficulties, the accuracy required identifying the correct level, and the inherent risks of the various positions.

A. Presently used Spinal Surgery Table

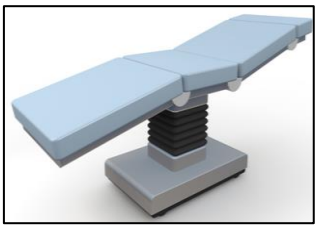

Fig. 2: Presently used spinal surgery table

II. COMMON SPINE AND DISC PROBLEMS

- Degenerative Disc Disease
- Bulging and Ruptured Discs
- Arthritis
- Spinal Instability
- Spinal Stenosis

III. PROCEDURES DURING SPINAL SURGERY

During spinal cord surgery one or more of the following procedures are done. Lamina is a bony arch that is part of the vertebrae. It protects the spinal cord.

- Laminotomy - Removal of part of the lamina.
- Laminectomy - Removal of the entire lamina.
- Discectomy - Removal of part, or all, of a disc.

- Cervical Corpectomy - Removal of part of the vertebral body and the disc on both sides of the vertebral bone in the neck.
- Fusion - Stabilization of two or more vertebrae by joining them with bone grafts.
- Fixation - Metal plates, rods, and screws placed to improve the likelihood of bone fusion.

IV. SPECIFICATION OF PROBLEM

In this review study it is proposed that existing surgical beds used in spinal surgeries which are made heavy and bulky, high skilled person required to operating. The cost of the bed is very high and also high maintenance is required.

V. OBJECTIVE

The aim of this review study is to design a surgical bed which is used in operating the spinal cord of human beings. The spinal surgical beds which are currently available in the market are very costly. They usually start from 2 lacks and pricing goes up to 78 lacks. This high price of the surgical bed makes the surgery very expensive. Hence in most cases the patients avoids this surgery which results in permanent immobility of the patient. In this project we are designing a surgical bed which will be easy to manufacture, easily adaptable, light weight and user friendly.

VI. REVIEW OF LITERATURE

The literatures related to spinal cord surgery and the operation tables and mechanisms used for this surgery are searched through medical journals, images, medical profile etc. and are discussed below.

A. Surgical Pillow Design by Optimal Head and Pillow Alignment-

1) Robert Rizza, XueCheng Liu &Zhiyuan Yang

In this study the authors have discussed the commercial pillow used in surgeries and its limitations. They observed that commercial donut pillows are used during lengthy surgical operations. With the patient anesthetized, the multiple pressure points on the head and wrinkling of the skin cut off blood circulation in the face, which leads to facial decubitus ulcers. Foam materials, which are used in these pillows, are very effective in reducing pressure points by transferring pressure into shear stress. However, this same shear stress leads to wrinkling of the skin which generates sores.

From the point of view of the pillow mechanics, pressure normal to the pillow surface is related to normal stress in the pillow. Reduction of this normal stress implies a reduction in pressure points and an increase in shear stress. However, an increase in the shear stress leads to increased wrinkling of the skin. Thus, the optimal pillow design, which reduces sores due to pressure points and wrinkling, would be characterized by the design where optimal values of the normal and shear stress are obtained. The optimal values in the normal and shear stress are affected by the orientation of the pillow with respect to the patient's face. Thus in order to find the optimal pillow design, a relationship between head orientation and pillow surface geometry must also be established.

The objective of this study was to design a custom surgical pillow by establishing optimal normal and shear stress components with respect to varying head orientations.

B. Finite-Element Study of the Performance Characteristics of an Intradural Spinal Cord Stimulator-

1) Nicole M. Grosland, George T. Gillies, Robert Shurig & Kirsten Stoner

This study used finite-element (FE) modeling to investigate the mechanical compliance, positional stability and contact pressures associated with a novel type of spinal cord stimulator that is placed directly on the pial surface of the spinal cord in order to more selectively activate neural structures for relief of intractable pain. The properties used in the model are those of the actual prototype devices employed in recent in vitro and chronic in vivo tests. The agreement between predictions and experimental observations serve to validate FE approach, which can now be used to further optimize the device's design and performance.

They have carried out and reported the results of a series of magnetic resonance (MR) imaging studies on patients, done for the purpose of measuring those characteristics of the spinal canal and ranges of spinal cord motion that are relevant to establishing the design parameters of the I-Patch device. A FE model was developed, validated against experimental data, and used to calculate stresses and contact pressures in response to placement of the I-Patch on a surrogate spinal cord model as well as during lift-off from the cord.

C. Design and Development of a Modular Medical Simulation Prototype for Pediatric Spinal Detethering Surgeries-

1) Joshua Bailey, Kalyani Nair, Alyssa Macuk & Christopher Frank

The objective of this project was to design, fabricate, and functionally evaluate a medical simulator to address the challenge of teaching the spinal detethering surgical procedure to neurosurgery residents. This simulator was designed to mimic anatomical and physiological characteristics of the lower lumbar region. Pressure sensors were used to quantify the forces that were applied to the spinal cord during the surgical procedure and a Lab VIEW program was developed to monitor the pressure profile.

The simulator was functionally evaluated by six residents, one fellow, one doctor, and two medical students. A conclusive, quantitative method for scoring these surgeries has not yet been developed, however, the residents and medical students were able to compare their procedures with those of more experienced doctors and fellows via qualitative methods. Future developments will include incorporating quantitative scoring methods as well as noise elimination hardware into the design.

D. A Cervico-Thoraco-Lumber multibody dynamic model for the estimation of joint loads and muscle forces-

1) Tsolmonbaatar Khurelbaatar, Kyungsoo Kim & Yoon Hyuk Kim

Investigations of mechanical joint loads on the human spine, such as the forces and moments applied to vertebral and facet joints and the forces that act on ligaments and muscles are essential in biomechanical and clinical research to

understand spinal disorders and injury mechanisms. However, the direct measurement of tissue loads on passive and active elements is normally very difficult due to the complexity of spinal structures. Therefore, computational musculoskeletal models have been developed to predict joint loads on the spine. Multibody dynamic models are currently used as computational models.

In this study, they have developed a detailed multibody dynamic musculoskeletal model of the cervico-thoraco-lumbar spine with passive and active structures and validated the model via comparisons with previously published experimental and computational studies.

E. Evaluation and Design of a Hospital Bed to be Manufactured and Used in China-

1) Brian Catalano Todd Coolidge

Objective of this study was to carry out the detailed study of the hospital beds which are presently used in China and to create evaluation and design for manufacturing these beds in China. Hospitals in China have begun to utilize the benefits of a technologically advanced bed. These beds however, are being imported from the leading technological nations including Japan and the United States for an exorbitant price. This increase in bed cost is then passed down to the patients further increasing the cost for quality healthcare and thus resulting in only the upper echelon of Chinese citizens being able to utilize technologically advanced hospital beds and hospital care.

Objective of this study was to research existing models of both Chinese and American brand hospital beds and to analyze the components and functions of each. They have carried a survey of number of nurses and patients in both the United States and China to determine additional features that could be useful in a modern hospital bed. Their aim was to design and manufacture a reliable, reproducible and marketable bed for the People's Republic of China.

F. AST Standards of Practice for Surgical Positioning

In this study they have proposed the Standards of Practice related to surgical positioning of the patient. The goal of the surgical position is to provide optimal visualization of, and access to, the surgical site that causes the least physiological compromise of the patient, while also protecting the skin and joints. When the patient has been administered anesthetic agents, the ability for the patient to communicate pain and pressure to the surgical team has been eliminated; therefore, the team now becomes responsible for the patient to ensure the positioning has been conducted in a safe manner, and the integumentary, musculoskeletal, respiratory and circulatory system functions have been preserved.

They have stated the three components of safe positioning of the surgical patient on an OR table which are knowledge, planning and teamwork. By following these Recommended Standards of Practice, the surgical team can reduce the chances of patient complications, related to positioning as well as contribute to preventing team members suffering a musculoskeletal injury.

G. Modifications to Patient Positioning for Cataract Surgery-

Suresh K. Pandey, MS (PGIMER), ASF (USA); and Vidushi Sharma, MD (AIIMS), FRCS (UK)

In this paper they have carried out the study of the patient lying supine with his or her head flat to optimize the red reflex and surgical view. If a patient has a medical condition that precludes lying supine, then both the patient and surgeon may be uncomfortable.

They have proposed that with simple modifications to the patient's position, successful, uncomplicated cataract surgery can be performed. They have performed a mock drill in the operating room to determine the best position for the procedure, which involved adjusting the microscope and phaco machine foot pedal.

H. Systematic Design of a Horse Surgical Table-

1) R Khodabakhshian, M. R, Bayati, M. Shakeri, M. Khojastepour

They have proposed that Surgery on a large animal like a horse, which is very heavy (500-800 Kg) and cannot be placed easily on an ordinary table, requires the specially designed surgical table.

In this study, the systematic design of a horse surgical table is described. The long term objective of the project is to resolve challenges in performing operation on heavy weight animal like a horse.

The result of the design is a horse surgical table with a main frame, the lifting mechanism, hydraulic system, the height adjustable platform and the auxiliary surface boards for resting the horse's legs, back, neck and head.

I. The Ideal Structural System in Hospital Buildings

1) Dr. Aziz Abid Dr. Omar Alghazawi

Clinical activity of each care department at hospital depends on medical and non-medical equipment. Advance medical equipment technology change unpredictable compare to the design and construction timescale.

Therefore design of the grid space and area built for main departments in hospital building are fixed to accommodate any future changes in medical equipment or furniture.

To reach and obtain the required area needed for each department it accommodate in the research furniture and medical equipment which maintain the required area regardless of any future changes in technology.

J. Side Saddle cataract surgery for patients unable to lie flat: learning from the past-

1) J Nair1 and T Rimmer Eye Department, Peterborough District Hospital, Peterborough, Cambs, UK

They have observed that Patients who cannot lie flat for cataract surgery pose a challenge if general anesthesia is too risky. They have suggested an alternative posture for the surgeon, which is not a big change for surgeons familiar with operating from the side.

The patient is positioned with the head rotated towards the surgeon and the foot pedals are placed parallel to the long axis of the operating table. Absorbent material is tucked into the patient's collar to protect it from the povidone iodine, which now tracks down the neck instead of towards the ear. The surgeon uses an inferno-temporal approach, but sits side saddle, with his thighs parallel to the long axis of the operating table and facing the head end. The optical axis of the microscope is inclined about 60° towards the horizontal, and the globe is tilted a little more super temporally than usual to optimize the red reflex if present.

K. An optimization framework for smoothing surgical bed census via strategic block scheduling-

1) Tim Carnes Devon Price Retsef Levi Peter F. Dunn Bethany J. Daily Sue Moss

Improving the flow of patients throughout a hospital is a key way to ensure both better and more cost-effective health care. Their approach to achieving this goal was increasing the number of resources available. The difficulty to employing this tactic was that it was often cost-prohibitive, which motivates the alternative method of getting better usage out of the existing resources and removing systemic inefficiencies. They have derived a method to increase the efficiency of the perioperative system at Massachusetts General Hospital (MGH).

This identifies the inpatient beds as a key bottleneck of the perioperative environment, and improving access to beds will result directly in improved flow. In order to understand the way in which beds are currently being used and identify opportunities for getting more use out of this resource, they performed a system-wide analysis of the average weekly bed usage, and break it down further into different patient populations.

L. Hydraulically Operated Surgical Table-

1) Sh. Kamal Singh Deputy Director (Mechanical)

In this paper they have proposed the requirement of operation table. OT Tables are designed to prevent the germs and to avoid infection to the patient and staff. Sweeping and curvy designs in OT tables are ideal, as they reduce the amount of seams that comes into the contact with atmosphere to avoid hiding of bacteria. Durability is another vital factor to look when manufacturing the OT tables. OT tables require wide range of facilities to be created to make the operation of a patient successful such as sectional top with large cut for patient drainage tray, built in kidney bridge, smooth gear mechanism to avail all required operating positions, hydraulic lifting/ lowering / tilting arrangements, wheel base for easy mobility/ stability with floor locking facility, sealed mattress, with / without orthopedic attachments etc. For calculation purposes the OT Table without orthopedic attachments is considered in this project profile.

M. Surgical Lift Project-

1) Dayna Anderson, Patrick Davis, Leslie Savage, and Monika Skowronska

The goal of Project was to design and build a lift for surgeons in the operating room. There were two very distinct goals for this project; the first looking at the short term and the latter looking towards the future. Their current chief concern was creating a lift that Dr. Muraszko feels comfortable using during surgery which can be easily transported. When looking towards the future, they envision a growing market for the lift as many women enter a variety of surgical fields. Since women are on average shorter than men, many "shorter" women will need assistance in some form to reach the proper operating height.

N. Validation of vibration testing for the assessment of the mechanical properties of human lumbar motion segments-

1) B.J. van Royen, A. de Boer, J.H. van Dieen

Experimental modal analysis is a non-destructive measurement technique, which applies low forces and small deformations to assess the integrity of a structure. It is therefore a promising method to study the mechanical properties of the spine.

A non-destructive measurement technique that is used in engineering to examine the mechanical properties of structures and can be used to identify damage, such as cracks in aero plane wings, is experimental modal analysis.

Modal tests measure the response of a system to an applied dynamic load. After fast Fourier transformation, the resulting frequency response function (FRF) allows determination of modal parameters such as Eigen frequencies (ratio between stiffness and mass), vibration modes (pattern of motion) and damping.

O. Modeling and analyzing hospital surgery operations management-

1) Marie Persson

More efforts are needed in order make the best use of resources and to keep cost under control. One of the most critical and expensive resources in a hospital is the operating theatre.

This thesis aims to investigate the potential of computer-based modeling for supporting healthcare decision makers to improve management policies related to the hospital operating theatre by improving patient scheduling and resource allocations.

VII. CONCLUSION

Study of all types of the presently available beds used in spinal surgeries is carried out. From the above study the possible alternatives for the modification as low cost surgical bed attachment can be developed. This can help the researcher to have easy access to the work done in the past in this case.

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