Clinical Gait Analysis after Sacrectomy Using the Closed Loop Reconstruction Technique: a case report

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***Abstract*—Total 'en bloc' sacrectomy is a complex surgical procedure needed for the resection of tumours in the sacral region. This procedure has major consequences on the load bearing ability and mobility of patients after surgery due to the delicate anatomy of the region affected. The stabilization technique used to reconnect the spine to the pelvis plays a major role in restoring the load-bearing ability of the lumbopelvic region. The purpose of this study is to evaluate the biomechanics of the closed loop lumbopelvic reconstruction technique with respect to the construct used and the resulting mobility of the patient. One patient underwent 3D gait analysis after surgery: independent gait function was maintained, with a residual asymmetry pivoting on the right and a reduced propulsion ability associated to slow gait.**

***Keywords*— Gait Analysis, Chordoma, Sacrectomy, Stabilization.**

I. Introduction

PRIMARY bone tumours of the sacrum are very rare. Of those, chordoma is a slow growing low malignancy tumour [1]. Due to the mild symptoms, it usually is diagnosed in advanced stages making surgical interventions the first treatment of choice for large sacral chordomas [2]. The anatomy of the spino-pelvic region is very delicate and plays a key role in the stability of the body [3], making the total "en bloc" sacrectomy one of the most challenging procedures in spine surgery [1]. Aiming at optimal oncological results, wide surgical margins are preferred for the resection of the tumour, leading to the loss of the connection between spine and pelvis and of the sacral nerve roots, potentially affecting a patient's mobility. The anatomical connection must be reconstructed to restore the load-bearing ability of the spino-pelvic structure [4]. Different reconstruction techniques following sacrectomy currently exist, aiming to assure a stable fixation between the pelvis and lumbar spine, using implants to achieve bony fusion [2]. The current work is part of a larger study on the biomechanics of the closed loop fixation technique following total "en bloc" sacrectomy.

The purpose of the present work is to provide an overview of the neuromuscular function and gait capabilities of the patient following the surgery.

II. Methods

A. Surgical Technique

The surgical stabilization was implemented using the closed loop technique (CLT) developed at the National Centre for Spinal Disorders, Budapest. This technique uses a single U-shaped rod to restore the lumbo-pelvic junction. The construct uses two to three pairs of bicortical iliac screws and lumbar transpedicular screws to anchor it to the iliac bone and the lumbar spine. This stabilization method has demonstrated to improve the stability of the lumbo-pelvic junction during flexion-extension and rotation [4]. The non-rigid construct allows for more harmonic stress distribution and decreases the chances of instrumentation failure resulting from the excessive stress on the iliac bone and the rod used. To achieve bone fusion, CLT uses morselized autographs from the iliac bone (Figure 1) [4].

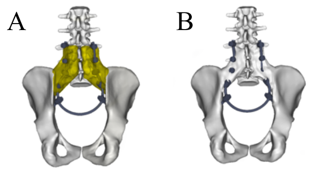

Fig. 1, Closed Loop Reconstruction Technique. (A) U-shaped rod and screws with autograft location between pelvis and lumbar spine, (B) bony fusion achieved one year after surgery.

B. Patient

One male patient (42 years old) presented with a sacral chordoma and underwent a total "en bloc" sacrectomy with a closed loop reconstruction. Following the surgery, the patient lost all nerve roots below L5.

C. Postsurgical Evaluation

The patient underwent 12 follow up CT scans in a period of six years. The CT scans were evaluated to quantify the deformation of the construct in the 3D space as this technique aims to have a non-rigid construct. Over the years the construct achieved bone fusion with increased bone density and regeneration at the site of the resection.

D. Motion Analysis

Six years after surgery, the patient (48 years of age, w: 90.5kg, h:185cm) underwent a gait analysis session. The patient was requested to walk back and forth along a straight path, mounting a full body plug-in-gait marker setup. Marker trajectories were acquired using a 6-camera motion analysis system (VICON MXT40, UK), and ground reaction forces (GRF) using a force platform (AMTI OR6, USA) mounted half-way along the path. The patient completed five trials in total. Spatio-temporal parameters were calculated. Gait speed was normalized to body height (BH) and stance time was calculated as a percentage of the total stride time. Joint kinematics and kinetics were calculated from marker trajectory and ground reaction forces using Vicon's Nexus-PIG protocol. Mean and standard deviation of data per gait cycle were calculated over the 5 available repetitions per side and compared to normative data [5].

III. Results

A. Gait characteristics

TABLE I

	Control	*Right Leg*	*Left Leg*
Gait Speed/BH (%BH/s)	71.36 (10.23)	40.25 (3.05)	39.27 (2.34)
Stride Time (s)	1.10 (0.10)	1.37 (0.06)	1.36 (0.06)
Stance Time (%GC)	62.64 (1.97)	65.34 (3.80)	71.66 (2.40)

Table 1, Mean (SD) temporospatial gait characteristics of the right and left leg compared to healthy subjects.

The patients' gait speed was reduced compared to the control on both sides while the stride time increased. Stance time in percentage of the gait cycle lasted longer than in the control, particularly on the left side, showing an asymmetric gait.

B. Joint Angles

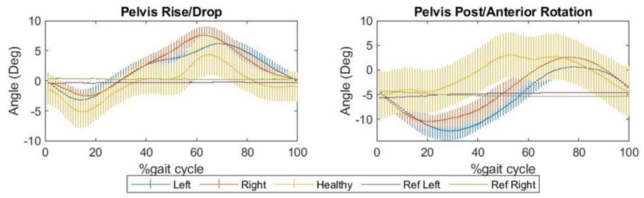

Fig. 2, Time-series kinematics of the pelvis of the left and right leg compared to healthy subjects.

Kinematic analysis of gait showed a forward leaning of approximately 20° of the pelvis and the trunk throughout the gait cycle, resulting in the disappearance of hip extension on both sides during the final part of the stance phase (push-off). An increased rise of the pelvis could be observed associated with an increased adduction of the hip, particularly on the right side. A pivoting behaviour was also demonstrated by an increased anterior rotation of the left pelvis during stance. Alterations in the kinematics of lower limbs were minor, with a lack of knee flexion peak and increased ankle extension at the beginning of the stance phase and increased flexion of the knee during the swing phase.

C. Joint Moments

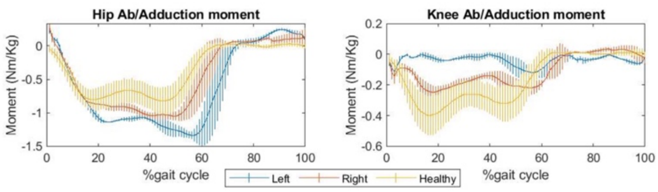

Fig.3, Times series kinetics of the hip and knee during abduction/adduction of the left and right leg compared to healthy subjects.

GRF components were reduced in the AP and ML directions, particularly on the right side. At the hip, the initial flexion moment peak almost disappeared on both sides resulting in an extended and maintained extension moment, significantly increased on the left side. Adduction moments increased on both sides, particularly on the left. Joint moments were, on the other hand decreased at the knee, particularly on the left side, while differences were minor at the ankle.

D. Joint Powers

Power analysis showed a significantly reduced power generation at the ankle during push off on both sides, associated to a power absorption peak as opposed to a normal power generation peak at the hip. Knee power absorption peak was slightly increased at the beginning of the stance phase.

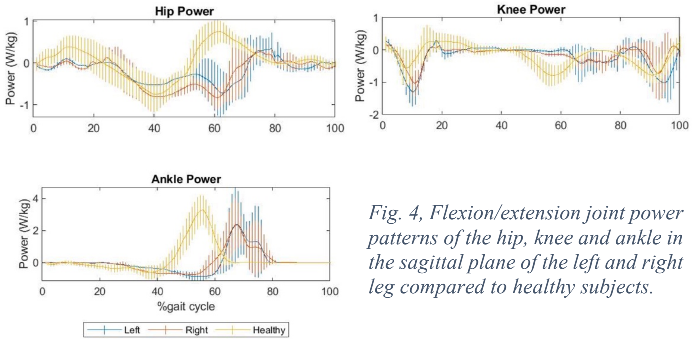

Fig. 4, Flexion/extension joint power patterns of the hip, knee and ankle in the sagittal plane of the left and right leg compared to healthy subjects.

IV. Discussion

Locomotor biomechanics following total sacrectomy has only been described by one prior study by J. Smith *et al.* (2014) [2]. This is the first work done to assess gait after total sacrectomy when using the closed loop technique.

Following surgery, the patient was able to walk independently, with minor gait alterations for compensating the lost neural function. The resulting gait was slow and slightly asymmetric with increased support on the left leg and right pivoting and a reduced propulsion power at the hip and ankle. On the other hand, joint mobility was close to normal at all the joints, distally in particular. The forward leaning of the pelvis and the trunk could serve as a compensation technique to guarantee progression, exploit gravity and reduce muscle force requirements of the hip and knee extensors in particular.

The observed gait alterations can be related to the impaired function in the hip muscles resulting from loss of the sacral nerve roots after sacrectomy, although EMG analysis is required to better support this hypothesis.

Acknowledgement

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