Impairment-driven cancer rehabilitation in patients with neoplastic spinal cord compression using minimally invasive spine stabilization: A single-center retrospective study

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Research

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Abstract

Background: Neoplastic spinal cord compression is a cause of severe disability in cancer patients. To prevent irreversible paraplegia, a structured strategy is required to address the various impairments present in cancer patients.

Methods: We retrospectively reviewed 27 consecutive patients with neoplastic spinal compression who were treated with minimally invasive spine stabilization (MISt). We classified the impairments of patients through our multidisciplinary tumor board based on spine-specific factors, skeletal instability and tumor growth. The neurological deficits, ambulation status, progress of pathological fracture, incidence of vertebral collapse, postoperative implant failure were examined. Changes of the Barthel index (BI) scores before and after surgery were investigated throughout the clinical courses.

Results: The average duration to ambulation was 7.19±11 days, and we observed no collapse or progression of paralysis except in four cases of complete motor paraplegia before the surgery. We noted good functional prognosis in patients capable of ambulation within seven days and in patients who could survive longer than three months after the surgery.

Conclusions: In various cancer patients with neoplastic spinal cord compression, skeletal instability as the primary impairment is a good indication for MISt, as the patients showed early ambulation with improved BI scores.

Background

According to the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) developed by the World Health Organization, impairment refers to a problem associated with a bodily structure or organ, whereas disability refers to a functional limitation in a particular activity [1]. Cancer patients suffer from a set of impairments, partially due to the disease itself, and partly due to the adverse effects of treatment. Both physical and psychological impairments contribute to decreased quality of life which may result in disability. Recently, many researchers have demonstrated that cancer rehabilitation improves physical impairments at every stage along the treatment course for a variety of cancer types [2–5].

Impairment-driven cancer rehabilitation is a model advocated by Silver et al. since 2013. They emphasized the importance of identifying physical impairments because disability is frequently driven by the interactions of multiple physical impairments. Therefore, this model involves screening and treating impairments all throughout the course of care to minimize disability and maximize the quality of life [6].

Among the different impairments in cancer patients, neoplastic spinal compression is unique because the severity of impairment (or of disability) does not correlate with the pathological grade of malignancy. The impairment is neurological-oriented [7–9]; it is only associates with spine-specific factors which are the level of spinal cord injury and the volume of spinal compression. Thus, we assume that disability from neoplastic spinal compression can be prevented with appropriate interventions aimed to treat these spine-specific factors and such interventions would be effective even in patients at the palliative stage.

Clinically, we evaluated the spine-specific factors based on two independent biological aspects: skeletal instability and tumor growth. Skeletal instability is caused by the destruction of bony structures. A pathological fracture may occur and fragments in the spinal canal may cause paraplegia. In terms of tumor growth, the volume of rapidly-growing tumors in the spinal canal may threaten the spinal cord directly, even if skeletal stability was preserved. Regarding surgical approaches, wide resection has been considered the curative treatment because both local and marginal resection may result in higher rates of recurrence. This is why conservative surgeries for local control have rarely been performed for these patients [10–11]. However, to treat skeletal instability, some surgical approaches have been reported [12–15].

Minimally invasive spine stabilization (MISt) with percutaneous pedicle screws (PPS) have shown advantages of relatively lower blood loss, less morbidity, shorter hospital stays, lower postoperative infections and immediate mobilization without the need for external bracing [13–15]. Several studies have reported improved activities of daily living (ADL) after MISt with PPS as a palliative surgery for patients with neoplastic spinal cord compression [13–15]. However, since most studies lack the impairment-driven approach, surgical indications still remain unclear.

In this study, we retrospectively reviewed 27 consecutive patients with neoplastic spinal compression who were treated with MISt and received immediate rehabilitation thereafter. Before the surgery, the status of impairment was evaluated based on both spine-specific factors and other factors. The neurological deficit, ambulation status, progress of pathological fracture, collapse, postoperative implant failure were examined. Furthermore, the relationship between the improvement of Barthel index (BI) [16] and prognosis was statistically analyzed.

Patients And Methods

Patients

This retrospective study was conducted at Nara Medical University Hospital. The study protocol was approved by the institutional review board of the hospital and was conducted in concordance with principles of the Declaration of Helsinki and with the laws and regulations of Japan. A consecutive cohort of 27 patients with neoplastic spinal cord compression from 2014 to 2017 who met the surgical indications described below were enrolled. The treatment strategy for all the patients was assessed by the multidisciplinary tumor board of our hospital. Informed consent was obtained through our website, those who opted-out were excluded. Follow-up periods averaged at 420 ± 357 days (range: 30-1305 days).

Surgical indication for MISt

Surgical indication for MISt was assessed comprehensively by the multidisciplinary tumor board for skeletal metastasis, based on clinical findings including (1) spinal instability, (2) radiological spinal compression, (3) prognosis, (4) feasibility for the stabilization surgery (whether patients had multiple spinal lesions), (5) presence of pain or neurological deficits. Spinal instability was evaluated using the spinal instability neoplastic scale (SINS) score [17]. Score ≥ 7 was classified as potentially unstable or unstable. To assess the degree of cord compression, the 6-point epidural spinal cord compression (ESCC) grading scale was used [18], and neurological findings were evaluated. Regarding prognosis, we referred to the Revised Tokuhashi score [19] and the new Katagiri score [20]. Patients' with estimated life expectancy of ≥ 1 month were assessed for surgery. The surgery involved a short posterior fixation with PPS placed at two vertebral levels above and two level below the lesion. Patients with multiple spinal lesions expanding the vertebra of planned fixation level were deemed unfeasible for surgery. In addition to fixation, posterior decompression was performed in cases of tumors occupying only the posterior epidural space and were not considered hemorrhagic by radiological and pathological findings.

Multidisciplinary tumor board for skeletal metastasis

The multidisciplinary tumor board (MDTB) for skeletal metastasis at Nara Medical University Hospital was established in 2010. Since then, the disability/impairment statuses of each patient have been evaluated. The treatment plans for approximately 100 patients have been discussed per year. The monthly board meetings are attended by physicians, medical oncologists, radiation oncologists, diagnostic radiologists, physiatrists, orthopedic oncologists, spine surgeons, advanced practitioners, oncological nurses, and clinical support staffs. Besides the regular monthly board meetings, web discussions are held for emergency cases selected based on the electronic medical record system of the hospital. Cases eligible for presentation include new or existing outpatients or inpatients with skeletal metastasis. Based on these discussions, all patients would immediately receive intensive and regular adjuvant treatments including radiation therapy, chemotherapy, palliative care, and rehabilitation.

Outcome evaluation

Clinical outcomes evaluated were neurological deficits using the Frankel Scale (A-E) [21], duration to the start of ambulation exercises, the progress of pathological fractures, incidence of vertebral collapse, post-operative implant failure, BI scores before and after surgery, and overall prognosis.

Statistical analysis

Statistical analysis was performed using the JMP14.0 software (SAS Institute, Cary, NC, USA) and G*Power software 3.1(University of Dusseldorf). A p-value of < 0.05 was considered statistically significant. The Wilcoxon signed-rank sum test was used to evaluate differences in the BI scores before and after surgery because the data was nonparametric. Univariate logistic regression models were applied to identify the predictor variables associated with BI score gain, these factors include tumor progression, ESCC grade, SINs, preoperative ambulation status and radiation therapy status. Respective ODD ratios and p-values were calculated.

Results

Patients’ characteristics

Table 1 shows the patients' characteristics. Patients included 16 men and 11 women; the mean age at surgery was 65.1 years. Location of primary lesion was lung in 8 patients (29.6%), liver (or gallbladder) in 4 (14.8%), colon in 3 (11.1%), prostate in 3 (11.1%), kidney in 3 (11.1%), breast in 3 (11.1%), stomach in 1 (3.7%), bone in 1(3.7%), and lymph node in 1(3.7%). Frankel's classification of preoperative paralysis was B in 4 patients (14.8%), C in 3 (11.1%), D in 3 (11.1%), and E in 17 (63%). Degree of cord compression assessed with the ESCC grading scale included 1 patient with grade 1a (3.7%), 1 with grade 1b (3.7%), 1 with grade 1c (3.7%), 7 with grade 2 (25.9%), and 17 with grade 3 (63%).

Duration to ambulation and functional prognosis after surgery

Table 2 shows the clinicopathological data and functional prognosis, including days to ambulation recovery. Although the spinal cord was highly compressed in almost 90% of patients (7 patients had ESCC grade 2 and 17 patients had grade 3), the mean duration to ambulation was 7.19 ± 11 days. Considering the high rate of patients with severe cord compression, it is noteworthy that all patients achieved ambulation after surgery, except for 4 patients who had complete motor paraplegia before surgery (patients 5, 22, 24, 27). There was no case of implant failure or vertebral collapse after surgery.

Neurological recovery on the Frankel scale

Table 3 shows the neurological recovery in terms of the Frankel scale. Neurological deficiency was improved to or maintained at grade E in 16 patients, remained unchanged in 6 patients (in grades B, C, D) and worsened in 5 patients.

Change of the Barthel index (BI) before and after surgery

Figure 1 presents the changes of the BI scores after surgery. BI score comparisons before and after surgery in all patients showed statistically significant increments, suggesting improvement of ADL (Fig. 1A, $p < 0.05$, power = 0.97, effect size = 0.8). Figure 1B shows the changes of the BI scores in patients capable of ambulation within 7 days, which also suggested significant improvement of ADL ($p < 0.05$, power = 0.92, effect size = 0.8). However, we were unable to evaluate those in patients incapable of ambulation within 7 days due to underpowered statistics (C). Changes of the BI scores in patients alive with disease (AWD) are shown in Fig. 1D, and those in patients dead of disease (DOD) are shown in Fig. 1E. While patients AWD were statistically underpowered, patients DOD showed no statistical differences in the BI scores after surgery (power = 0.83, effect size = 0.8). Figures 1F and 1G present changes of the BI scores in patients dead within 3 months after surgery and patients alive 3 months after surgery, respectively. The latter presented significant improvement of ADL ($p < 0.05$, power = 0.96, effect size = 0.8). Data on patients who died within 3 months were statistically underpowered.

Univariate logistic analysis

Univariate logistic analysis was performed to identify the predictor variables associated with the BI score gains. However, no statistical significance was shown with tumor progression, ESCC grades, SINs, preoperative ambulation status, or radiation therapy status.

Discussion

MISt with PPS supports skeletal stability in patients with neoplastic spinal cord compression, but does not have any effects on tumor growth. In order to control tumor growth, additional chemotherapy and/or radiotherapy are required. Ambulation status has considerably improved after the surgery. Although many presented with high degrees of cord compression before surgery, early ambulation was achieved in almost all patients, suggesting that metastatic paraplegia can be prevented even if skeletal instability has caused critical physical impairment to the patient (Table 2). Rehabilitation was started one day after the surgery, and involved tasks like sitting, standing, and walking, similar to rehabilitation programs after general (not oncological) spine surgeries. Four patients, who had complete motor paraplegia before the surgery, did not show any improvement in physical function, yet the stabilized spine enabled them to train in wheelchair riding with decreased pain.

Skeletal stabilization through MISt using PPS may affect neurological recovery. In our series, neurological deficiencies were improved or maintained in 22 patients, but worsened in 5 patients. Tumor volume leading to spinal compression is dependent on tumor growth speed. However, in the cases in which tumor growth was relatively slow or controlled by adjuvant therapy, stabilization surgery decreased swelling of the spinal cord and hence skeletal pain, eventually supporting neurological recovery (Table 3).

Results from the comparison of BI scores before and after surgery may suggest a more detailed surgical indication. Although this study is a retrospective review with limited number of cases, sufficient statistical power supported the efficacy of MISt in the improvement of ADL in patients with neoplastic spinal cord compression (Fig. 1A). Furthermore, through subgroup analyses, we found good functional prognosis in patients capable of ambulation within 7 days (Fig. 1B), and in patients who could survive longer than 3 months after the surgery (Fig. 1G). In the former comparison, patients whose general conditions worsened because of impairments from underlying diseases unrelated to spine could not ambulate within 7 days even with a stabilized spine and eventually showed no improvement of ADL. From the latter, we postulate that a 3-month life expectancy is a possible indication for MISt with neoplastic spinal cord compression.

To avoid preventable disabilities from metastatic paraplegia, spine-related impairments should be distinguished from other oncological impairments and further characterized based on two independent biological aspects, skeletal instability and tumor growth, as were done through the MDTB of our hospital. Two representative cases of malignant spinal compression are shown in Fig. 2. Figure 2A shows a case with skeletal instability as the major factor for impairment, while Fig. 2B shows a case with tumor growth as the major factor for impairment. In terms of effective interventions to avoid disability, the former is an indication for spinal stabilization surgery, while the latter is an indication for additional chemotherapy and/or radiotherapy, typically in patients with treatment-sensitive tumors. However, our study involved a population of patients whose BI scores did not improve after surgery. Further investigations are required to estimate the possible progress of impairments due to underlying conditions unrelated to the spine.

Conclusion

In patients with neoplastic spinal cord compression, impairment-identification is of utmost importance. First of all, spine-specific impairments should be distinguished from other oncological impairments. These spine-specific impairments should then be evaluated based on two aspects: skeletal instability and tumor growth. For patients whose primary impairment was skeletal instability, MISt enabled them to ambulate early, this was reflected by their improved BI scores.

Declarations

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Ethics approval and consent to participate

This study was approved by the Nara Medical University Institutional Review Board. Informed consent was obtained through opted-out from all patients.

Consent for publication

Written informed consent was obtained from the patient and legal guardian for publication of these reports.

Availability of data and materials

All date used and analyzed during this study are available from the corresponding

author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

IY and KA performed the study concept and design. KA and TS analyzed the results.

SH, MY, IE, OA, TM and KS contributed to collecting the cases and performed

surgeries. FH and TY made some meaningful suggestions. All authors have

read and approval the final manuscript.

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Tables

Due to technical limitations, the tables are only available as a download in the supplemental files section.

Figures

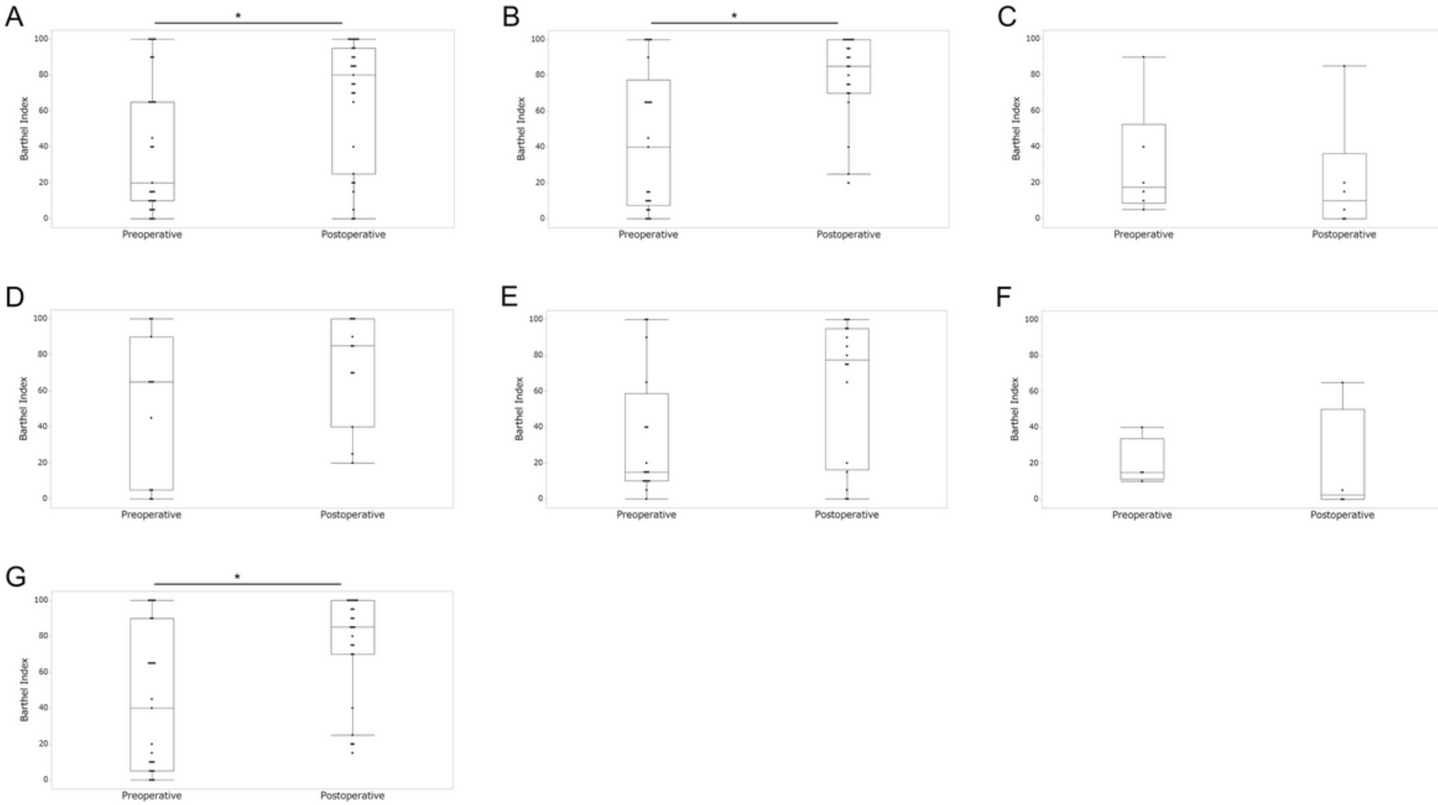

Figure 1

Changes in the BI scores after surgery in patients. A. Comparison in all patients before and after surgery. B. Changes in the BI scores in patients capable of ambulation within 7 days C. Changes in the BI scores in patients incapable of ambulation within 7 days D. Change in the BI scores in patients AWD E. Change in the BI scores in patients DOD F. Changes in the BI scores in patients who died of disease within 3 months of surgery G. Changes in BI scores in patients who died of disease after more than three months.

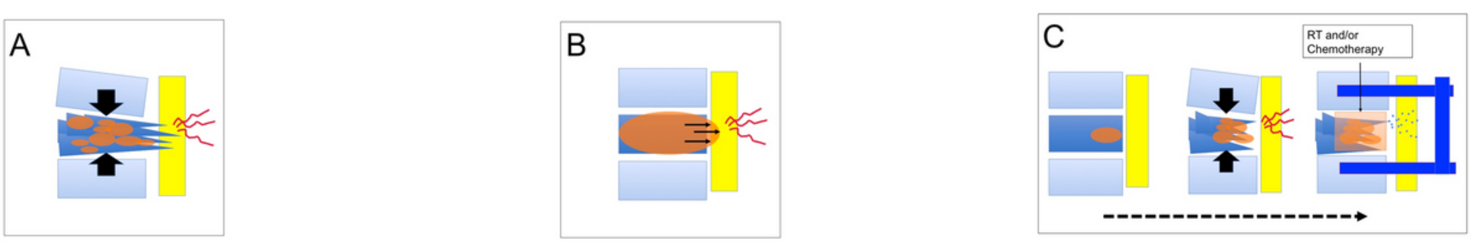

Figure 2

Schema of malignant spinal compression. Two representative statuses of malignant spinal compression are shown in (A) and (B). (A) represents skeletal instability as the major factor for impairment. (B) represents tumor growth as the major factor for impairment. In the former case, spine stabilization may avoid the disability while in the latter, chemotherapy and/or radiotherapy are required (C)

Supplementary Files

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