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**A simple model to predict survival in patients with metastases of the long bones: the Bollen model**

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**Introduction**

Bone metastases of the long bones can cause pain and fractures. Radiotherapy is the standard treatment when pain is the predominant symptom. Surgical treatment is necessary for patients with an (impending) pathologic fracture to obtain a functional and painless limb. To decide on the optimal treatment for a patient, prediction of survival is essential to determine the invasiveness of the treatment. To aid in the prediction, several models have been developed for patients with metastases of the long bones. Katagiri et al. (Cancer Medicine, 2014) established the most recent model, containing primary tumor type, presence and extent of visceral metastases, six laboratory values, performance score, previous chemotherapy, and presence of multiple bone metastases. Although the details of categorization of primary tumor types are strong, the model can be difficult to use in daily practice due to the many variables. The Bauer model (Bauer et al. Acta Orthop Scand, 1995) contains 5 clear variables and is easier to use in that regard. A downside of this model however is its less distinctive outcome regarding short-term survival estimations. A simple, yet predictive model developed for spinal bone metastases is the Bollen model (Bollen et al. Neuro-oncology, 2014). Based on three variables, patients are categorized into four prognostic groups: A (best survival; > 12 months) through D (worst survival; <3 months). The model is based on 1043 patients with spinal metastases and includes clinical profile (favorable, moderate or unfavorable; based on primary tumor type and contributing factors such as availability of effective systematic treatment), Karnofsky performance score (KPS; 10-70 *vs.* 80-100), and presence of visceral or brain metastases (figure 1). It would be very efficient if this model were also applicable for patients with metastases of the long bones.

**Purpose**

To determine whether the Bollen model is applicable for patients with metastases of the long bones.

**Patients and Methods**

Patients treated for symptomatic metastases of the long bones between 2000 and 2010 at our institution were identified by searches of surgery, radiotherapy, pathology, and oncology databases. This resulted in 551 patients (mean age 64 years ± 13.6). Data concerning demographics, primary tumor, metastasis, treatment, and follow-up were retrospectively collected. Survival times were estimated from the moment of first local treatment of the first long bone metastasis in the study period. Survival curves were estimated using the Kaplan Meier method and compared using log rank test.

**Results**

Median overall survival of the entire group was 7 months (95%CI 5.8 – 8.2). At 2 years, 79% of all patients had died. The clinical profile was favorable in 200 patients (36%), moderate in 158 patients (29%) and unfavorable in 193 patients (35%). Visceral or brain metastases were present in 214 patients (39%). KPS was high (80-100) in 203 patients (37%) and low (10-70) in 192 patients (35%). The KPS was unknown in 156 cases and these patients could not be scored for the model. The remaining 395 patients were scored according to the Bollen model. Forty-eight patients (12%) were categorized as group A, 120 (30%) as group B, 135 (34%) as group C, and 92 (23%) as group D (table 1). The estimated median survival for the prognostic groups was 24 months (95%CI 19.8-28.2), 14 months (95%CI 11.3-16.7), 5 months (95%CI 3.7-6.3), and 2 months (95%CI 1.5-2.5) for groups A, B, C, and D, respectively (p<0.01), as shown in table 1.

**Conclusion**

Numerous models for survival prognosis of patients with bone metastases have been developed over the years. Currently, the increasing attention for personalized treatment stimulates the development of specific models. This however leads to complex models with an overwhelming number of variables, which in turn decreases the practical value of the model. The Bollen model is a straightforward model with 3 variables that can be answered easily, and has proven to be specific especially for short-term survival. The results of this study show that although the model was based on patients with spinal bone metastases, it is also applicable for patients with metastases of the long bones. The model makes distinct survival prognoses for this patient population. Validation with a larger patient population will possibly reveal minor improvements to make the model as predictive as possible, while maintaining its practical value.

| Prognostic group | Patients (n) | Median survival (months) | 95% confidence interval | Hazard ratio | 95% confidence interval |
|---|---|---|---|---|---|
| A | 48 | 24 | 19.8 – 28.2 | reference | |
| B | 120 | 14 | 11.3 – 16.7 | 1.58 | 1.11 – 2.45 |
| C | 135 | 5 | 3.7 – 6.3 | 3.36 | 2.35 – 4.80 |
| D | 92 | 2 | 1.5 – 2.5 | 5.71 | 3.90 – 8.35 |

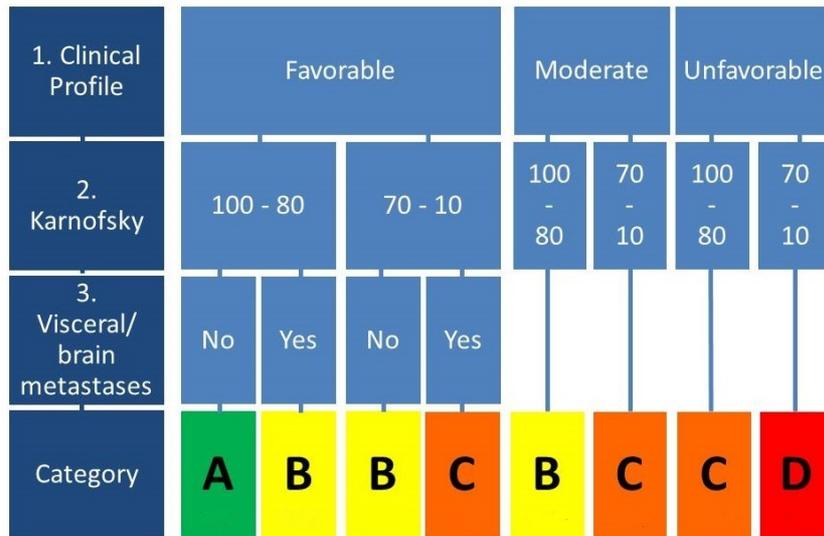Table 1. Median survival and hazard ratios for categories according to Bollen model.



Figure 1. The Bollen model