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Fractures in children and adolescents with spina bifida: the experience of a Portuguese tertiary-care hospital

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AIM The morbidity associated with osteoporosis and fractures in children and adolescents with spina bifida highlights the importance of osteoporosis prevention and treatment in these patients. The aim of this study was to examine the occurrence and pattern of bone fractures in paediatric patients with spina bifida.

METHOD We reviewed the data of all paediatric patients with spina bifida who were treated in our centre between 1999 and 2008.

RESULTS One hundred and thirteen patients were included in the study (63 females, 50 males; mean age 10y 8mo, SD 4y 10mo, range 6mo–18y). The motor levels were thoracic in six, upper lumbar in 22, lower lumbar in 42, and sacral in 43 patients. Of the 113 patients, 58 (51.3%) had shunted hydrocephalus. Thirty-six (31.8%) were non-ambulatory (wheelchair–dependent [unable to self-propel wheelchair] n=3, wheelchair-independent [able to self-propel wheelchair] n=33), 13 were partial ambulators, 61 were full ambulators, and three were below the age of walking. Forty-five fractures were reported in 25 patients. The distal femur was the most common fracture site. Statistical analyses showed that patients with higher levels of involvement and in wheelchairs had a significantly increased risk of having a second fracture (p<0.001). Spontaneous fractures were the principal mechanism of injury, and an association was identified between fracture mechanism, type of ambulation, and lesion level: the fractures of patients with higher levels of motor functioning and those in wheelchairs were mainly pathological (p=0.01). We identified an association between risk of a second fracture, higher motor level lesion, and non-ambulation. There was an increased risk of having a second fracture after a previous spontaneous fracture (p=0.004).

INTERPRETATION Data in this study indicate a high prevalence of fractures in patients with spina bifida.

In congenital paraplegia caused by myelomeningocele, the body lacks the usual axial burden on the legs, muscular activity, and sensation.[1] There is a direct influence of working muscles on the remodelling process of the growing tibia. Post-mortem studies of patients with spina bifida reveal a thin and atrophic cortex of the tibia with a diminished number of Haversian systems and large remodelling cavities.[2] In fact, patients with spina bifida have lower bone mineral density and are at risk of pathological bone fractures.[3] The clinical status of children with spina bifida can be significantly worsened by the effects of secondary osteoporosis, including fractures and subsequent further immobilization, and the leg bones of patients with spina bifida have an additional risk of fractures after inactivity (e.g. postoperatively).[1,4–6]

Our primary aim in this study was to examine the frequency and characteristics of fractures in paediatric patients with spina bifida. A secondary aim was to identify other variables that may contribute to the presence of fractures, such as neurological level, shunted hydrocephalus, syringomyelia, type of ambulation, mechanism of injury, and prolonged immobilization. We hypothesized that patients who use wheelchairs would have a higher fracture frequency.

METHOD

The study, conducted at Dona Estefânia Hospital, Lisbon, Portugal, was a retrospective evaluation of the hospital records of all patients with a diagnosis of spina bifida who were followed at our unit between 1999 and 2008. Our centre is a state tertiary-care paediatric hospital located in an urban setting, which serves patients from the entire country. The study was approved by the hospital's ethics committee.

Patients were included if they had spina bifida confirmed by in-patient documentation, were aged 0 to 18 years, and were still living. Patients were excluded from the study if they had had no clinic visit in the past 2 years, if their medical records were unavailable, if they had been transferred to another care centre, or if they had spina bifida occulta or isolated caudal regression syndrome. Once the eligible population of patients

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with spina bifida had been assembled, charts were reviewed to evaluate data from their health records. In addition, we also interviewed at least one parent of each patient, either face to face or by telephone, to identify all occurrences of fractures, surgical interventions, and hospitalizations in other centres.

The neurological level and ambulatory status of each participant were determined by two graduate assistants, from the departments of Physical Medicine and Rehabilitation and Paediatric Neurology. The neurological level in the patients was categorized as thoracic, upper lumbar (L1–L2), lower lumbar (L3–L5), or sacral. The International Myelodysplasia Study Group criteria for assigning motor levels was used to evaluate the level of neurological involvement.[7]

Ambulatory status was recorded, using a modified version of the International Myelodysplasia Study Criteria Manual,[8] as non-ambulatory, partially ambulatory, or fully ambulatory. Non-ambulatory wheelchair users were subdivided into those who were totally dependent on their wheelchair and could not move it themselves (i.e. they needed to be driven by caregivers; termed 'wheelchair-dependent') and those who were able to propel the wheelchair without physical assistance ('wheelchair-independent'). Partially ambulatory patients could move around their own home; fully ambulatory patients could move further afield. Because our study included patients younger than 15 months, we added the category of 'below the age of walking'.[9]

The mechanism of injury was divided into spontaneous fracture (without known trauma), minor trauma (trivial injury), and major stress. Spontaneous fractures and those due to minor trauma were defined as pathological. For each participant, we recorded date of birth, sex, neurological level, ambulation status, presence of shunted hydrocephalus, shunt revision, or syringomyelia, number and location of fractures, age at occurrence of each fracture, and mechanism of injury.

We also reviewed each patient's history of neurosurgical, orthopaedic, and other surgical interventions and medical conditions for evidence of prolonged immobilization, focusing on the length of time spent immobilized after each procedure and the interval between removal of the cast and the occurrence of fractures.

Statistical differences were evaluated with a χ^2 test and Fisher's exact test using StatXact 8 (Cytel Studio, Cambridge, MA, USA) and MATLAB version 7.1 (Math Works, Cambridge, UK). A logistic regression model was used to adjust the data on lesion level and ambulatory status for patients who presented with a second fracture. Occurrence of a second fracture was the dependent variable, with lesion level and ambulatory status as the risk factors being tested. For a given patient, i, the probability of occurrence of a second fracture Z_i is related to the level of lesion $X=x_i$ and type of ambulation $Y=y_i$, by the following equation:

$$P(Z_i = 1|X = x_i, Y = y_i) = \frac{e^{\beta_0+\beta_1 x_i+\beta_2 y_i}}{1 + e^{\beta_0+\beta_1 x_i+\beta_2 y_i}}$$

All calculations were performed using Statistica 6.0 (StatSoft, Tulsa, OK, USA). The parameters β_0, β_1, and β_2 were estimated by the maximum likelihood method. The quasi-Newton method was used to maximize the maximum likelihood loss function. The relationship between these risk factors and second fracture occurrence was estimated using odds ratios and 95% confidence intervals (CI). Statistical significance was set at $p<0.05$.

What this paper adds

- We characterise fractures in paediatric patients with spina bifida.
- We identify variables that may contribute to the occurrence of fractures.
- The aetiology of fractures is characterized.
- Clinical characteristics are identified that could help to identify children at risk of suffering multiple fractures.

RESULTS

Patient characteristics

Billing records identified 152 patients with qualifying diagnoses according to the 9th revision of the International Statistical Classification of Diseases and Related Health Problems.[10] Of these, two died, one had spina bifida occulta, and six had isolated caudal regression syndrome. Additionally, 30 were excluded because they had not been seen in the past 2 years, were over 18 years old, or were transferred to another care centre.

Of the remaining 113 patients who met the study criteria and had available records, 50 were male and 63 were female (male:female ratio 0.8:1). The participants' mean age was 10 years 8 months (SD 4y 10mo, range 6mo–18y). The motor level was thoracic in six, upper lumbar in 22, lower lumbar in 42, and sacral in 43 patients. Fifty-eight patients (51.3%) had shunted hydrocephalus, and 36 (31.8%) had shunt revision.

Thirty-six patients were non-ambulatory (three wheelchair-dependent, 33 wheelchair-independent), 13 were partial ambulators, 61 were full ambulators, and three were below the age of walking.

Fracture characteristics

Forty-five fractures were reported in 25 of the 113 patients (22.1%; 95% CI 15.70–28.75%). Thirteen patients had one fracture, six had two fractures, four had three fractures, and two had four fractures. Age at the time of fracture ranged from 0 to 16 years, with a mean age of 6 years 8 months, a median of 6 years 10 months, and a mode of 8 years; the fractures occurred before the age of 9 years in 71.1% of patients. Eleven of the 25 patients with fractures were male, and 14 were female (Table I).

Most fractures occurred in the lower extremities (Table II). The distal femur was the most common site, with nine fractures (20%; 95% CI 10.19–29.81%), followed by the proximal femur and proximal tibia, with seven fractures each (15.5%; 95% CI 6.67–24.44%), and the femoral mid-shaft, with four fractures (8.9%; 95% CI 1.91–15.87%). Only two fractures occurred in others regions (4.4%; 95% CI 0–9.50%). There were 26 left-sided injuries (two during delivery) and 12 right-sided injuries; in seven patients, the affected side was not reported.

Eight fractures (17.7%; 95% CI 8.4–27.15%) occurred in four of the six patients with a neurological deficit at the thoracic level (66.6%; 95% CI 35.01–98.32%), 25 fractures

Table I: Number of fractures according to clinical and ambulatory status

Clinical and ambulatory status	Fracture, *n*	No fracture, *n*	*p* value
Females	14	49	1.000[a]
Males	11	39	
Shunted hydrocephalus	18	40	0.169[b]
Shunt revision	14	22	
Cord tethering release	10	39	
Syringomyelia	10	39	0.820[c]
Wheelchair-dependent	1	2	<0.001[a]
Wheelchair-independent	17	16	
Partially ambulatory	4	9	
Fully ambulatory	3	58	
Below the age of walking	0	3	
Total	25	88	

[a]Fisher's exact test (two-tailed); [b]χ^2 test for contingency tables; [c]one-sample proportion test (H0: p=0.5).

Table II: Fracture distribution

Site		Fractures, *n*
Femur	Total	23
	Proximal	7
	Mid-shaft	4
	Distal	9
	Unspecified	3
Knee		2
Tibia and fibula	Total	17
	Tibia, proximal	7
	Tibia, distal	3
	Fibula, proximal	1
	Fibula, distal	2
	Tibia and fibula, proximal	1
	Tibia and fibula, mid-shaft	1
	Ankle	2
Lower extremity	Unspecified	1
Other	Parietal bone (during delivery)	1
	Clavicle	1
Total		45

(55.5%; 95% CI 43.37–64.74%) occurred in 11 of the 22 patients with a deficit at the upper lumbar level (50%; 95% CI 32.46–67.54%), 11 fractures (24.4%; 95% CI 13.91–34.98%) occurred in nine of the 42 patients with a deficit at the lower lumbar level (21.4%; 95% CI 11.01–31.84%), and only one fracture (traumatic) occurred in one of the 43 patients with a deficit at the sacral level (2.3%; 95% CI 0–6.11%).

Spontaneous fractures were the principal mechanism of injury (29 fractures, 64.4%; 95% CI 52.71–76.18%). At least one child was initially treated for clinically suspected osteomyelitis. Only 16 fractures (35.5%; 95% CI 23.82–47.29%) followed known trauma, which was significant in only eight of these fractures.

Risk factors associated with fracture occurrence

The frequency of fractures was increased in patients with higher levels of neurological involvement (Fisher's exact test p<0.001; Table SI, published online only). There was no significant association between level of motor lesion and fracture location (p=0.1; Table III).

A significant association was found between the incidence of fractures and ambulatory status, with wheelchair-independent patients having a significantly increased risk of fracture (Fisher's exact test p<0.001). More than 50% of the wheelchair-independent patients (17/33; 95% CI 37.20–65.83%) had at least one fracture (see Table I).

Using the χ^2 test, we did not detect an association between neurosurgical interventions (first shunt, shunt revision, and release of cord tethering) and the occurrence of fractures (p=0.169; see Table II). Neither sex nor syringomyelia were associated with the occurrence of fractures (p=1.000, p=0.820 respectively; see Table II).

Using Fisher's exact test, we found a significant statistical association between the mechanism of fracture and motor lesion level (p<0.001; Table SII, published online only). Statistical analysis also showed associations between the mechanism of fracture and ambulation type and level of lesion (p=0.010). Pathological fractures were more prevalent in patients with lesions at the thoracic and upper lumbar levels (29/37 fractures, 78.4%, 95% CI 67.25–89.51%). All fractures in fully ambulatory patients with lesions at the lower and sacral levels were linked to major trauma (Table IV). Patients without fractures were more likely to be ambulatory (see Table II) with lesions at low motor levels.

Risk factors associated with a second fracture

The occurrence of a second fracture in patients with spina bifida results from an interaction between several factors (Fig. S1, published online only). Clinical observations suggest an association between the frequency of second fracture occurrence, the lesion level, and the type of ambulation. In a preliminary approach, we intended to predict the occurrence of a second fracture from the lesion level and ambulation type, because these factors are both non-invasive and easily evaluated. Logistic regression was used to explore two potential risk factors for the occurrence of a second fracture. The odds ratio was 2.68 for the parameter β_1 (95% CI 0.95–7.56) for unit chance on the level of lesion and 0.37 for the parameter β_2 (95% CI 0.12–1.14) for unit chance on the ambulatory status.

For the χ^2 statistic in the likelihood ratio test, used to compare the likelihood of the null model (all parameters β_0, β_1, and β_2 are null) with the likelihood of the fitted model, p was <0.001. Since the p value was significant, we can state that the estimated model yielded a significantly better fit to the data than the null model; that is, there was strong evidence that patients with higher levels of neurological involvement and in wheelchairs have an increased risk of having a second fracture. This model allows one to interpret the level of lesion and the ambulatory status as risk factors for the occurrence of a second fracture.

On Fisher's exact test, the occurrence of a spontaneous first fracture increases the risk of a second fracture (p=0.004; Table SIII, published online only): 11 of 15 patients who had a previous spontaneous fracture sustained a second fracture, compared with only one of 10 patients with a previous non-spontaneous fracture.

Table III: Site of fractures according to level of motor involvement

Motor level	Femur, *n* (%)		Tibia/fibula, *n* (%)		Other, *n* (%)[a]		Total, *n*
Thoracic	6	(75)	1	(12)	1	(12)	8
Upper lumbar	14	(56)	9	(36)	2	(8)	25
Lower lumbar	3	(27)	6	(55)	2	(18)	11
Sacral	0	(0)	1	(100)	0	(0)	1
Total	23	(51)	17	(38)	5	(11)	45

p=0.1 (Fisher's exact test, two-tailed) for comparison of fractures of the femur and the tibia/fibula, excluding other fractures. [a]'Other' refers to the sum of fractures of the knee (unspecified), lower extremity sites not documented, and fractures of the clavicle and parietal bone.

Table IV: Occurrence of fractures in relation to mechanism of injury, ambulation type and level of lesion

		Mechanism of injury		
Ambulation type	Lesion level	Pathological fracture, *n*	Major trauma, *n*	Total, *n*
Wheelchair-dependent	Upper lumbar	3	0	3
Wheelchair-independent	Thoracic	6	2	8
	Upper lumbar	20	2	22
	Lower lumbar	3	0	3
Partial ambulator	Lower lumbar	5	1	6
Full ambulator	Lower lumbar	0	2	2
	Sacral	0	1	1
Total		37	8	45

p=0.01 (Fisher's exact test, two-tailed).

Association between fractures and prolonged inactivity

Eighteen of the 45 fractures occurred within 3 months, 15 within 2 months, and 14 within 1 month of some form of treatment that caused prolonged immobilization, with most of the cases involving orthopaedic surgery. The most frequent musculoskeletal interventions were for foot and hip. We detected only one fracture 3 months after a neurosurgical procedure (primary shunt).

Ten fractures occurred within 1 month of the cast being removed: seven of these fractures occurred after removal of a hip spica cast following hip surgery (six fractures in the femur and one knee fracture), and three occurred after removal of a foot cast following foot surgery (all fractures in the leg bones). Seven of these fractures occurred on the same day as the cast was removed. The remaining 27 fractures were not related to any form of treatment.

Case descriptions

An 8-month-old female with paraplegia at the upper lumbar motor level sustained a fracture of the left proximal femur associated with physiotherapeutic exercise and was immobilized with a cast. Three days after removal of the cast, the patient suffered a spontaneous fracture of the casted extremity.

A 3-year-old male with paraplegia at the upper lumbar level had a fracture of the left knee (unspecified part) recorded on the same day as cast removal, which occurred during physiotherapy exercises. The injury was detected following a gentle crack with subsequent swelling in the thigh.

An 11-year-old male with paraplegia at the lower lumbar level was hospitalized for aggravation of an episode of periorbital cellulitis and had a fracture of the proximal tibia after a prolonged period of recumbence.

A 13-year-old female with paraplegia at the upper lumbar level sustained a fracture of the distal femur after a long period of inactivity related to a burn on the foot.

One fracture of the femur was identified in association with birth in a male child with paraplegia at the thoracic motor level.

DISCUSSION

In 113 children and adolescents with spina bifida, 45 fractures were detected in 25 patients (22.1%). The frequency of fractures in our research is consistent with those reported in the literature (range 11–30%).[1,11–16]

As can be found in other analyses,[1,11,14] our data show that the level of neurological involvement is directly related to the incidence of fractures.

Sex was not associated with the occurrence of fractures. The recent article of Dosa et al. [17] showed similar results.

Ambulatory status affected the incidence of fractures, with wheelchair-independent patients having a greater risk of fracture. This is likely to be related to the fact that non-ambulatory children with a chronic severe disability have low bone mineral density[18] with subsequent morbidity.[19]

In our study, the most common site of fracture was the distal femur. An analysis of the literature shows that this is the most common site of fractures in children with immobility, independent of the primary disease.[19,20] The sites of fractures in patients with spina bifida were similar to those encountered in patients with spinal-cord injury.[21] We failed to find verte-

bral fractures, which suggests a possible protective effect on vertebral fractures among patients with spina bifida who use wheelchairs. This may be due to maintenance of load on the spine while sitting. These results are also analogous to the population with spinal-cord injury.[17,22]

Lock and Aronson suggested the possibility that fractures involving the lower extremities occur distal to the level of neurological involvement, with fracture of the femur being more frequent with higher motor levels (thoracic) and fracture of the tibia more frequent with lumbar motor levels.[11] In our survey, there was no significant relationship between the motor lesion and the fracture location, but there was undoubtedly a trend suggestive of this relationship.

Fractures may occur without significant trauma and, due to the lack of sensation, may be imperceptible. Pathological fractures were the main cause of fracture and manifested with local warmth, redness, swelling, and an increase in temperature. Pathological fractures should, therefore, be suspected even in patients presenting with only swelling of the extremity.

We identified an association between the mechanism of the fracture and the type of ambulation and level of the lesion. In patients with higher levels of neurological involvement, who were in wheelchairs, fractures were mainly pathological. None of the patients with lesions at the sacral level experienced a spontaneous fracture. The hypothesis is that less torque is needed to produce failures in bone in people with higher motor level lesions than in individuals who have lesions at lower levels who largely sustain independent gait.

Most of the fractures (71.1%) occurred before 9 years of age, which is similar to the findings of Lock and Aronson. This could be because a higher number of surgical interventions are necessary in younger patients to attempt gait improvement.[11]

In our data, it was possible to detect an association between prolonged postoperative inactivity and fractures in several cases, and this has already been documented in previous studies.[1,5,11]

After orthopaedic procedures, fractures that occurred within 1 month of the plaster being removed were more common when the patient was immobilized in a spica cast following hip surgery and less common when the patient was in a short-leg cast after foot surgery. This risk factor should be taken into account when one considers operations in patients with spina bifida. Drummond et al. suggested immobilizing the hip for only 4 weeks after femoral osteotomy.[5]

The association between neurosurgical interventions and the occurrence of fractures was not statistically significant. When we looked for a temporal linkage, this relationship was clearly less evident than for orthopaedic interventions. This finding is consistent with the results of Parsch.[1]

The association identified between the risk of a second fracture and higher motor level lesion and non-ambulation could help physicians identify children at risk of experiencing multiple fractures.

The increased risk of having a second fracture after a spontaneous fracture could explain why most orthopaedic specialists make a diagnosis of osteoporosis in children and adolescents only in the presence of one fragility fracture (beyond the presence of low bone mineral density), i.e. only in the presence of what would be considered a complication of osteoporosis in adults.[23]

Our data support the hypothesis that fractures should be expected in patients with spina bifida after major reconstructive surgery. Whenever possible, the period of immobilization following surgery should be shortened,[5,11,24] and weight bearing on the paralysed legs must be allowed as soon as possible.[1] If several operations are necessary, many authors recommend undertaking them all at one stage, or at least within the period that the patient needs to be immobilized for one of the procedures.[5,24] Whenever possible, a spica cast should be avoided, and when long-leg casts are used to prevent post-immobilization fractures, a major issue is to avoid crawling for the first 3 weeks. When some immobilization is needed, a bulky Webril dressing provides less rigid immobilization than a plaster cast.[11] If a plaster cast is unavoidable, it should be constructed to allow the earliest opportunity to stand.[1]

Limitations of the study

As in any retrospective study design, the incidence of fracture and its relationship to prolonged inactivity may be underestimated owing to the varying quality of information in the medical records. Further, it was not possible in all cases to characterize the location of fractures in long bones.

CONCLUSION

Data in this study support the high prevalence of fractures in patients with spina bifida. We caution that particular care must be used to avoid fractures in these patients after postoperative inactivity.

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ONLINE MATERIAL/SUPPORTING INFORMATION

Additional material and supporting information may be found in the online version of this article.

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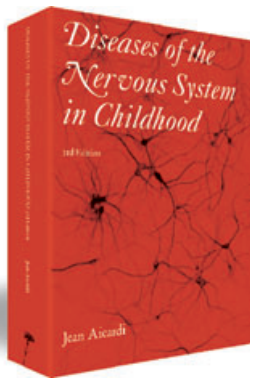

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