

Spinal cord compression by extramedullary haematopoietic tissue in a patient with β -thalassaemia

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Abstract

Background: A high index of suspicion for spinal cord compression due to extramedullary haematopoiesis should be considered in thalassaemic patients with neurological complaints especially in patients from the Mediterranean countries.

Purpose: To report a case of spinal cord compression by extramedullary haematopoietic tissue in a patient with β -thalassaemia who was operated upon successfully and followed up for six years after surgical decompression with no recurrence.

Methods: A 31-year-old female patient presenting with progressive neurological dysfunction of 3 months duration, caused by extramedullary haematopoiesis, compressing the spinal cord underwent surgical decompression. One year later the patient presented with a similar condition due to a higher lesion in the spine and was treated similarly.

Results: A thoracic hemilaminectomy allowed the complete resection of both masses. Histopathological findings disclosed extramedullary haematopoietic tissue. A 6 year follow-up revealed complete relief of the symptoms and control of the lesion, with no recurrence or new lesions.

Conclusion: Prompt recognition of this condition is essential to prevent further neurological injury. Complete recovery after surgical decompression is reported in this case. (p80-87)

Key words: Extramedullary haematopoiesis, spinal cord compression and thalassaemia

Introduction

Thalassaemias are inherited disorders of haemoglobin synthesis. Their clinical severity varies widely, ranging from asymptomatic forms to severe or even fatal entities. Extramedullary haematopoiesis (EMH) is a common finding in thalassaemic patients with or without symptoms depending on the location.

The most common sites of EMH are the liver, spleen and lymph nodes. Other sites include the adrenal glands, kidneys, breasts, dura matter, adipose tissue and skin.^{53, 60, 61} Intrathoracic EMH is found in a small percentage of patients (11 - 15%).^{16,43} In an even smaller percentage, intrathoracic masses can compress the spinal cord and cause neurological symptoms.³

We report a patient with β -thalassaemia major who presented with symptoms and signs of thoracic spinal cord compression due to an epidural erythropoietic tissue compression who was operated upon twice at two different sites (T4-T6 and T8-T11 in the first procedure and T1-T4 in the second).

Case Report

We present a 31-year-old female patient, who was first diagnosed to be thalassaemic at the age of 8. Past history showed she suffered from arrhythmias and was controlled by digoxin. She underwent splenectomy and cholecystectomy at the age of 20 years. She presented to our service in February 2000, complaining of progressive mid backache, lower limb weakness and paraesthesia, progressing over a period of 3 months, with more recent problems of urinary

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and stool incontinence. Physical examination revealed a thin, underweight patient with pallor, severe jaundice, hepatomegaly, ejection systolic murmur grade 3 and thoracic scoliosis convex to the right. On neurologic testing, both upper limbs were normal in power, sensation and reflexes. She had sensory level on her trunk at T4; lower limb examination revealed pyramidal weakness of grade +/- 3/5, worse on the right side. Deep tendon reflexes were hyperactive with extensor planter responses and bilateral sustained clonus in knees and ankles. Laboratory analysis showed Hb=7g/dl and elevated direct and indirect serum bilirubin.

Computed tomography (CT) (Fig. 1) and magnetic resonance imaging (MRI) (Figs. 2 and 3) of the thoracic spine revealed a posterior epidural lobulated mass compressing the spinal cord at two levels extending from T4-T6 and from T8-T11. In addition, widening of the ribs and expansion of the medullary cavity in the vertebral bodies and ribs (trabeculations) were seen.



Figure 1 - Spinal CT scan before first surgery showing the characteristic trabeculations of the body, transverse processes, lamina and the attached rib due to extramedullary haematopoietic tissue. Within the spinal canal extensive haematopoietic tissue is seen extradurally compressing the cord to the left side and anteriorly.

Among the classical changes of the bones usually encountered in patients with thalassaemia are the striking expansion of the erythroid marrow (as a result of the ineffective erythroid production), that widens the marrow spaces and causing thinning of the cortex of ribs, long bones and flat bones. Plain radiographs of bones reveal a lacy trabecular pattern. Additionally, there is the classic “Hair on End” appearance of the skull, which results from widening of the diploic spaces as observed on plain radiographs. The maxilla may overgrow, which results in maxillary overbite and prominence of the upper incisors. These changes contribute to the

classic “chipmunk face” observed in patients with thalassaemia major.



Figure 2 - MRI of thoracic spine before the first surgery showing extradural haematopoietic tissue compressing the spinal cord from T4-T6. **Figure 3** - Preoperative MRI before the first surgery showing extradural haematopoietic tissue compressing the spinal cord from T8-T11

Due to the deterioration of her neurological condition (progressive paraparesis and sphincteric problems), it was agreed to perform surgical decompression; T4-T6 and T8-T11 hemilaminectomy with total excision of a very vascular large and thick lobulated sheath of ectopic epidural mass compressing the thoracic spinal cord, under the guidance of neurosurgical microscope.

Postoperative period was uneventful. Numbness disappeared and muscle power of the lower limbs improved dramatically within one month. The patient was fitted with thoracic belt and was able to return to work three months following surgery.

Unfortunately, one year later, the patient presented again with progressive left thigh weakness and unstable gait. On neurological testing, left more than right lower limb pyramidal weakness was seen of grade +/- 3/5.

Cervico-thoracic MRI was performed which revealed a second posterior epidural lobulated mass extending from T1-T4 (Fig. 4). As a preoperative measure to elevate her Hb (which was 6 g/dl), she received 5 units of packed red blood cells and was operated upon where T1-T4 hemilamin-

ectomy and total excision of the ectopic erythropoietic tissue was achieved. Postoperatively, she improved dramatically. Six years follow-up with MRI performed yearly, showed no recurrence or spinal cord compression at any level (Fig. 5). Clinically she remained well.

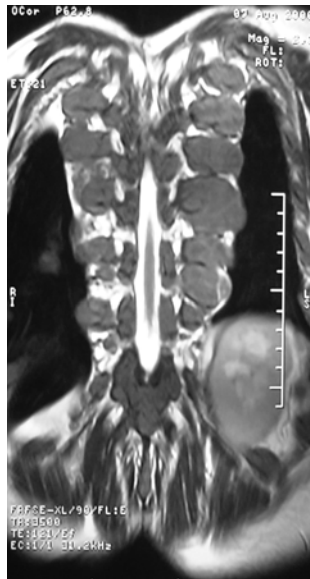


Figure 4 - Postoperative MRI after first surgery showing decompressed spinal cord from T8-T12 with a new extradural haematopoietic tissue compressing the spinal cord at upper levels T2-T4.



Figure 5 - Postoperative MRI, six years after second surgery showing decompressed spinal cord and extramedullary haematopoietic tissue

Histopathologic sections on both procedures showed a well circumscribed mass, surrounded by a thick fibrous capsule, fibroconnective and adipose tissue. The mass consisted of a mixed population of haematopoietic cell precursors, namely erythroid, myeloid and megakaryocytic cells. The haematopoietic cells were present in all stages of maturation; however no significant increase in immature or atypical cells was identified. The haematopoietic cells formed sheets and were not mixed with bony trabeculae which is consistent with an extramedullary haematopoietic tumour.

Discussion

β -Thalassaemia is a quite common inherited disorder in Mediterranean countries. In thalassaemia a decrease in the rate of production of certain globins chain or chains (α , β , γ , δ) impedes Hb synthesis and creates an imbalance with the other normally produced globin chains. As two types of chains (α and non- α) pair with each other at a ratio of 1:1 to form normal Hb, an excess of normally produced type is present and accumulates in the cell as unstable product leading to the destruction of the cell. This imbalance is the hallmark of all forms of thalassaemia. The type of thalassaemia usually carries the name of the under produced chain or chains. This reduction varies from complete absence (β^0) to a slight decrease β^+ .

Thalassaemia is classified into α -thalassaemia and β -thalassaemia. The former varies from silent carrier to major α -thalassaemia which is incompatible with life. On the other hand β -thalassaemia has many types which are silent carrier β -thalassaemia, β -thalassaemia trait, β -thalassaemia intermedia, β -thalassaemia associated with β chain structural variants and β -thalassaemia major.

Extra haematopoiesis thalassaemic patients are very common, however spinal cord compression due to EMH is extremely rare. The first case was described by Gatto⁽¹⁹⁾, et al in 1954 and one report revealed an incidence of only 0.8%.⁴⁸

A number of mechanisms have been postulated in the literature to account for the predilection for the involvement of the spinal column and precisely the thoracic spine and these include:

- Direct extension of hyperplastic bone marrow through trabeculations in the proximal ends of the ribs.^{55,46}
- Dura matter has an erythropoietic potential during foetal life therefore there are primitive remnants that lead to this phenomenon and this might also explain the absence of bone erosion or fracture which should be present if there was direct extension from the vertebral bodies.^{49,52}
- Development of the extramedullary haematopoietic tissue from branches of the intercostal veins.¹²

In addition, some authors argue that the narrow central canal and limited mobility of the thoracic spine predispose itself to spinal cord compression.^{1,33,56}

In almost all of the reported cases the site of the lesion was lower thoracic spine but in our case the upper thoracic spine was also involved up to the limit of T1 which we believe emphasizes the second theory; direct extension of the hyperplastic bone marrow located in the dorsal spine and ribs since the first rib is in relation with the seventh vertebral body.

The diagnosis of spinal cord compression due to EMH is made clinically and radiologically. A history of thalassaemia and auxiliary evidence of EMH such as hepatosplenomegaly and lymphadenopathy may raise the clinical suspicion. Plain radiographs often reveal well demarcated paraspinal masses and bony changes associated with chronic anaemia such as trabeculation, widened ribs or thickened calvaria.^{15,30} Magnetic resonance imaging is currently the gold standard for demonstrating spinal EMH.^{13,21,31} Computed tomography is a valuable investigation for patients in whom MRI is contraindicated or unavailable.⁶²

The main controversy remains in the best method of treatment, whether 1) multiple blood transfusions (to down regulate erythropoietin production), 2) radiation therapy (to halt the production of overgrown marrow tissue), 3) surgical decompression, or 4) a combination of any of the above. The relative benefit of one treatment over another has not been clearly established due to the infrequency of this disorder.

Many authors argue that transfusion therapy can be used as a diagnostic tool and the sole treatment modality for patients with thalassaemia. It is used to relieve chronic anaemia, suppress EMH, inactivating those tissues which revert to those of normal size, and as the principal treatment modality in cases of spinal EMH where surgical decompression or radiotherapy were contraindicated, as in pregnancy or severe anaemia.⁶² However, it carries a major risk of infectious disease transfer, iron overload, formation of antibodies and other such problems. Additionally, the

improvement is usually incomplete and the symptoms recur shortly after and it will have no effect on oedema or cord compression. It can, however, be used as a diagnostic method to obviate the need for surgery or radiotherapy in mild spinal cord compression.

Since haematopoietic tissue is extremely radiosensitive, radiotherapy has been reported to yield excellent results with neurological improvement observed as soon as 3-7 days after initiation of treatment.^{28,54} However, the lack of tissue diagnosis before radiotherapy is given is taken as an argument against radiotherapy. A high risk of recurrence of up to 19% is also taken as a drawback of radiotherapy.⁴⁶

Regarding steroid treatment in such cases, we believe that by their general effect of reducing oedema due to various aetiologies, steroids may improve a patient's neurological status temporarily, however, steroids cannot be used to differentiate between numerous causes of cord compression and, thus, are not diagnostic but could be potentially misleading.

It is well known that surgical treatment for spinal EMH cord compression is effective in terms of immediate relief of cord compression in cases of rapid progressive neurological progression with the advantage of obtaining a histopathological diagnosis. However, disadvantages include risk of general anaesthesia, cardiovascular instability due to anaemia, and incomplete excision in cases of diffuse involvement.

We reviewed the literature and found 89 cases of EMH causing spinal cord compression treated via different modalities since 1954 up to the present date. Out of 89 cases, 12 patients were treated by surgery alone, 9 of them reported complete response (75%), 13 patients were treated by transfusion alone, 8 of them had complete response (62%) and 42 patients were treated by radiotherapy alone, 24 of them had complete response (57%). Surgery was combined with other methods in 16 patients, 15 of these were with radiotherapy, 9 of which had complete response (60%). Transfusion was also combined mainly with radiotherapy in 6 patients, 3 of them reported complete response (50%) (Table 1).

Table 1 - Reported thalassaemic patients with spinal cord compression secondary to extramedullary haematopoiesis

Number	Year	Author	Age/sex	Treatment	Outcome	Ref
1	1954	Gatto, et al	26/M	S&R	CR	19
2	1958	Close, et al	60/M	S&R	NR	11
3	1964	Sorsdahl, et al	40/M	S	CR	58
4	1965	Hongladarom & Hongsaprabhas	26/M	S	NR	24

Table 1 / cont'd

5	1968	Cathuen, et al	40/M 47M	S S&R	CR CR	7
6	1969	Ross & Logan	23/F	R	CR	50
7	1975	Luyendijk, et al	42/M	S&R	PR	33
8	1977	Mihindukulasuriya, et al	24/F	S	CR	36
9	1977	Cross, et al	25/F 44/M	S&R S&R	CR CR	14
10	1980	Prabhaker, et al	21/M	S&R	CR	48
11	1980	Issargisil, et al	24/M 22/M 34/M 37/M 19/F 32/M 25/F 26/M 40/M 17/M 29/M 23/M	Transfusions R R/steroids Transfusions R R R R R R/transfusions S&R R/transfusions	PR PR PR PR PR PR PR PR PR PR PR PR	27
12	1981	Francesconi, et al	24/F	R	CR	18
13	1981	Ahmed, et al	17/M	S	PR	2
14	1982	Papavassiliou	14/F 28/M 22/M	R R R	CR CR CR	44
15	1982	Abassioun & Amir-Jamshidi	19/M 19/M	S S	CR PR	1
16	1982	Luitjes, et al	55/M	S/R	PR	32
17	1982	Heffez, et al	72/M	S/R	PR	23
18	1983	Ibrahim, et al	17/M	S	CR	25
19	1983	David & Balasubramanian	28/F	S&R	CR	15
20	1984	Rossi & Pincelli	26/M	R	CR	51
21	1985	Pallotta, et al	21/M	R	CR	39
22	1986	Papavasiliou, et al	22/M 26/M 24/M	R R R	CR PR CR	41
23	1987	Mann ,et al	21/M	S	CR	34
24	1987	Papavasiliou & Sandilos	14/F 28/M 22/M 28/M 50/M	R R R R R	CR CR CR CR CR	45
25	1988	Jackson, et al	29/M	R	CR	28
26	1990	Papavasiliou, et al	22/M 26/M 24/M	R R R	CR PR CR	42
27	1991	Kaufman, et al	41/F 40/F	R R/Steroids	PR PR	30
28	1991	Singounas, et al	32/F	Transfusions	CR	57
29	1991	Hassoun, et al	22/M	R	CR	22
30	1991	Amir-Jamshidi, et al	16/M 14/M	S S	CR CR	5
31	1991	Singhal, et al	21/M 33/M	S/R R	PR PR	56

Table 1 / cont'd

32	1991	Chaljub, et al	22/M	R	PR	8
33	1992	Pantongrag-Brown & Suwanwela	27/M	R	PR	40
34	1992	Kalina & Hillstrom	30/F	R	PR	29
35	1993	Dore, et al	30/M 39/M	R R	PR PR	16
36	1993	Massenkeil, et al	38/F	R	CR	35
37	1994	Lau, et al	28/F	S	CR	31
38	1994	Shin, et al	22/M	S/R	CR	55
39	1995	Gouliamos, et al	20/M	R	CR	20
40	1995	Parsa & Oriезy	16/F 39/M	R/Transfusions Transfusions	PR PR	46
41	1996	Pistevou, et al	34/M 42/M 19/M	R/Transfusions R/Transfusions R/Transfusions	CR CR CR	47
42	1996	Ingemar, et al	23/M	R	CR	26
43	1997	Aydingoz, et al	27/M	R	PR	6
44	1998	Munn, et al	35/M	R	CR	37
45	1998	Silvana, et al	20/F	Transfusion	CR	17
46	1998	Coskun, et al	37/M	Transfusion/S	CR	13
47	2000	Alorainy, et al	25/F	Transfusion	CR	4
48	2001	Aliberti, et al	40/M 22/M	Transfusion Transfusion	CR PR	3
49	2001	Chourmouzi, et al	39/M 42/M	R R	CR CR	10
50	2002	Tze-Ching Tan, et al	17/M	S/R	CR	62
51	2003	Chehal, et al	21/F 21/M	Transfusion Transfusion	CR	9
52	2004	Salehi, et al	34/M	S/steroids	CR	54
53	2005	Niggemann, et al	21/M	R/R/S/R&S	CR	38
54	2005	Saghafi, et al	28/M	Transfusion	CR	53
55	2006	Tai, et al	15/F	Transfusion	CR	59

Abbreviations: S = surgery, R = radiation, T = transfusion, CR = complete response, NR = no response, PR = partial response. Published with permission from Saleh SA, Koski T, Ondra SL: Spinal cord compression in beta-thalassemia: Case report and review of the literature. *Spinal Cord* 2004, 42: 117-123

We recommend the following protocol on facing such a condition of spinal cord compression by extramedullary haemopoietic tissue :

- 1) Provide preoperative blood transfusion in all patients with Hb of less than 10. These patients usually present with Hb of 5-8 grams and this needs correction to ensure patients are fit for surgery and this may also assist to improve their neurological condition.
- 2) If power in patient's limbs is maintained at 3-5/5 and patient is ambulatory with no sphincteric impairment, patient may be referred for localized radiotherapy over the segment of spinal cord involved.
- 3) If power in patient's limbs is less than 3/5 and he is not ambulatory or if the patient has progressive rapid loss of neurological function or sphincteric impairment, he or she should undergo decompression surgically via laminectomy or hemilaminectomy.
- 4) Serial MRIs every 6 months for two years, followed thereby once yearly should be performed as a part of follow-up protocol.

Conclusion

Extramedullary haematopoiesis in thalassaemic patients is fairly common and may rarely cause neurologic conditions such as spinal cord compression. Prompt recognition of this

condition is essential to prevent further neurological injury. The method of treatment should depend on the neurological state of the patient and its progression to decide whether surgery for rapid decompression or less invasive measures, such as radiotherapy or blood transfusion for a slower but effective modality of treatment.

References

- Abbassioun K, Amir-Jamshidi A: Curable paraplegia due to extradural hematopoietic tissue in thalassemia. *Neurosurg* 1982, 11: 804-807
- Ahmed F, Tobin MS, Cohen DF, Gomez-Leon G: Beta thalassemia spinal cord compression. *NY State J Med* 1981, 81: 1505-1508
- Aliberti B, Patrikiou A, Terentiou A, Frangatou S, Papadimitriou A: Spinal cord compression due to extramedullary haematopoiesis in two patients with thalassaemia: complete regression with blood transfusion therapy. *J Neurol* 2001, 248: 18-22
- Alorainy Ibrahim A, Abdullah R, Al-Asmi B, Carpio Raquel del A: MRI features of epidural extramedullary hematopoiesis. *Eur J Radiol* 2000, 35: 8-11
- Amir-Jamshidi A, Abbassioun K, Ketabchi SE: Spinal extradural hematopoiesis in adolescents with thalassemia. Report of two cases and a review of the literature. *Childs Nerv Syst* 1991, 7: 223-225
- Aydingoz U, Oto A, Cila A: Spinal cord compression due to epidural extramedullary haematopoiesis in thalassemia: MRI. *Neuroradiol* 1997, 39: 870-872
- Cathuen JC, McLaurin LP, Foster MT, Roberts L: Spinal cord compression secondary to extramedullary hematopoiesis in two brothers: report of two cases. *Neurosurg* 1968, 29: 529-531
- Chaljub G, Guinto FC, Crow WN, Kumar R: MRI diagnosis of spinal cord compression in beta-thalassemia. *Spine* 1991, 16: 583-584
- Chehal Aref, Aoun Elie, Koussa Salam, Skoury Hadi, Koussa Suzanne, Taher Ali: Hypertransfusion: A successful method of treatment in thalassemia intermedia patients with spinal cord compression secondary to extramedullary hematopoiesis. *Spine* 2003, 28(13), E245-E249
- Chourmouzi Danai, Pistevou-Gompaki Kiriaki, Plataniotis Georgios, Skaragas Georgios, Papadopoulos Leonidas, Drevelgas Antonios: MRI findings of extramedullary hematopoiesis. *Eur Radiol* 2001, 11: 1803-1806
- Close AS, Taira Y, Cleveland DA: Spinal cord compression due to extramedullary hematopoiesis. *Ann Intern Med* 1958, 48: 421-427
- Cone SM: Bone marrow occurring in intercostal veins. *JAMA* 1925, 84: 1732-1733
- Coskun E, Keskin A, Suzer T, Sermez Y, Kildaci T, Tahta K: Spinal cord compression secondary to extramedullary hematopoiesis in thalassemia intermedia. *Eur Spine J* 1998, 7: 501-504
- Cross JN, Morgan OS, Gibbs WN, Cheruvanki I: Spinal cord compression in thalassemia. *J Neurol Neurosurg Psychiatry* 1977, 40: 1120-1122
- David CV, Balasubramaniam P: Paraplegia with thalassemia. *Aust NZ J Surg* 1983, 53: 283-284
- Dore F, Cianciulli R, Ravasio S, et al: Incidence and clinical study of ectopic erythropoiesis in adult patients with thalassemia intermedia. *Med Int* 1992, 7: 137-140
- Fonseca Silvana Fahel da, Figueiredo Maria Stella, Caçado Rodolfo Delfini, Nakandakare Fernando, Segreto Roberto, Kerbauy José: Spinal cord compression in β -thalassaemia: follow-up after radiotherapy. *Rev Paul Med* 1998, 116(6): 1879-1881
- Francesconi M, Vadala G, Franchini P, Ceechini A, Nappi G: Extramedullary haematopoiesis in a homozygous thalassaemia: a tomographic study of a case treated with radiotherapy. *Acta Neurol* 1981, 36: 602-605
- Gatto I, Terrana V, Biondi L: Comprssione sul midollo spinale da proliferazione di midollo osseo nello spazio epidurale in soggetto affetto da malattia di Colley splenectomizzato. *Haematologica* 1954, 38: 61-75
- Gouliamos AD, et al: Case report: magnetic resonance imaging of spinal cord compression in thalassemia before and after radiation treatment. *Clin Radiol* 1995, 50: 504-505
- Guermazi A, Miaux Y, Chiras J: Imaging of spinal cord compression due to thoracic extramedullary haematopoiesis in myelofibrosis. *Neuroradiol* 1997, 39: 733-736
- Hassoun H, et al: Spinal cord compression secondary to extramedullary hematopoiesis: a noninvasive management based on MRI. *Am J Hematol* 1991, 37: 201-203
- Heffez DS, Sawaya R, Udvarhelyi GB, Mann R: Spinal epidural extramedullary hematopoiesis with cord compression in a patient with refractory sideroblastic anemia. Case report. *J Neurosurg* 1982, 57: 399-406
- Hongladarom T, Hongsaprabhas C: Spinal cord compression due to extramedullary hematopoiesis in thalassemia hemoglobin E disease. *J Med Assoc Thai* 1965, 48: 1-9
- Ibrahim AW, Ibrahim EM, Mitry NM, Abdul Satira A, Kuppa A: Spinal cord compression due to intrathoracic extramedullary hematopoiesis in homozygous thalassemia. *J Neurol Neurosurg Psychiatry* 1983, 46: 780-782
- Ingemar SJ, Martina Pieter A van Doorn: Spinal cord compression due to extramedullary haematopoiesis in thalassaemia: a case report and review of the literature. *J Neurol* 1996, 243: 364-369
- Issaragrisil S, Piankijagum A, Wasi P: Spinal cord compression in thalassemia. *Arch Intern Med* 1981, 141: 1033-1036
- Jackson Jr DV, Randall ME, Richards F: Spinal cord compression due to extramedullary hematopoiesis in thalassemia: long term follow-up after radiotherapy. *Surg Neurol* 1988, 29: 389-392
- Kalina P, Hillstrom MM: MR of extramedullary hematopoiesis causing cord compression in beta-thalassemia. *Am J Neuroradiol* 1992, 13: 1407-1409
- Kaufmann T, Coleman M, Giardina P, Nisce LZ: The role of radiation therapy in the management of hematopoietic neurologic complications in thalassemia. *Acta Haematol* 1991, 85: 156-159
- Lau SK, Chan CK, Chow YY: Cord compression due to extramedullary hemopoiesis in a patient with thalassemia. *Spine* 1994, 19: 2467-2470
- Luitjes WF, Braakman R, Abels J: Spinal cord compression in a new homozygous variant of thalassemia. Case report. *J Neurosurg* 1975, 42: 212-216
- Luyendijk W, Went L, Schaad HD: Spinal cord compression due to extramedullary hematopoiesis in homozygous thalassemia: case report. *J Neurosurg* 1975, 42: 212-216
- Mann KS, Yue CP, Chan KH, Ma LT, Ngan H: Paraplegia due to extramedullary hematopoiesis in thalassemia. Case report. *J Neurosurg* 1987, 66: 938-940
- Massenkeil G, Wichmann W, Krummenacher F, Rhijner K: Reversible R-ckenmarkskompression durch extramedullare blutbildungsherde bei thalassamie. *Dtsch Med Wochenschr* 1993, 118: 100-106
- Mihindukulasuriya JCL, Chanmugan D, Machado F, Samarasinghe CA: A case of paraparesis due to extramedullary hematopoiesis in HbE-thalassemia. *Postgrad Med J* 1977, 53: 393-397

37. Munn RK, Kramer CA, Arnold SM: Spinal cord compression due to extramedullary hematopoiesis in beta-thalassemia intermedia. *Int J Radiat Oncol Biol Phys* 1998, 42: 607-609
38. Niggemann P, Krings Hans F, Thron A: Fifteen-year follow-up of a patient with beta thalassaemia and extramedullary haematopoietic tissue compressing the spinal cord. *Neuroradiol* 2005, 47: 263-266
39. Pallotta MG, Prececutti AS, Nucifora E, Fantl D, Arroyo J: Compresion medular en un paciente talasemico. *Sangre* 1985, 30: 921-926
40. Pantongrag-Brown L, Suwanwela N: Case report: chronic spinal cord compression from extramedullary haematopoiesis in thalassaemia - MRI findings. *Clin Radiol* 1992, 46: 281-283
41. Papavasilion C, Gouliamos A, Vlahos L, Trakadas S, Kalovidouris A, Pouliaides GR: CT and MRI of symptomatic spinal involvement by extramedullary haemopoiesis. *Clin Radiol* 1990, 42: 91-92
42. Papavasiliou C, et al: CT and MRI of symptomatic spinal involvement by extramedullary hematopoiesis. *Clin Radiol* 1990, 42: 91-92
43. Papavasiliou C: Tumor simulating intrathoracic extramedullary hemopoiesis. *Am J Roentgenol* 1965, 93: 695-702
44. Papavassiliou C: Radiotherapy of symptomatic tumor-simulating extramedullary hematopoiesis. *Int J Radiat Oncol Biol Phys* 1982, 8:1813-1820
45. Papvasiliou C, Sandilos P: Effect of radiotherapy on symptoms due to heterotopic marrow in β -thalassemia. *Lancet* 1987, 1: 13-14
46. Parsa K, Oriезy A: Nonsurgical approach to paraparesis due to extramedullary hematopoiesis. Report of two cases. *J Neurosurg* 1995, 82: 657-660
47. Pistevou-Gompaki K, Skaragas G, Paraskevopoulos P, Kotsa K, Repanta E: Extramedullary haematopoiesis in thalassaemia: Results of radiotherapy: A report of three patients. *Clin Oncol* 1996, 8: 120-122
48. Prabhakar S, Chopra JS, Khosla VK, Dash S, Banerjee AK: Spinal cord compression in homozygous beta thalassaemia. *Surg Neurol* 1980, 13: 351-354
49. Rice GPA, Assis LJP, Barr RM, Ebers GC: Extramedullary hematopoiesis and spinal cord compression complicating polycythemia vera. *Ann Neurol* 1980, 7: 81-84
50. Ross P, Logan W: Roentgen findings in extramedullary hematopoiesis. *AJR* 1969, 106: 604-613
51. Rossi F, Pincelli G: Computed tomography diagnosis of spinal cord compression secondary to epidural extramedullary hematopoiesis. *Diagn Imag Clin Med* 1984, 53: 255-258
52. Rowe DW, Barest G: Spinal cord compression caused by extramedullary hematopoiesis. *Am J Roentgenol* 1999, 173: 810-812
53. Saghafi Massoud, Shirdel Abbas, Lari Shahrzad M: Extramedullary hematopoiesis with spinal cord compression in β -thalassaemia intermedia. *Eur J Interl Med* 2005, 16: 596-597
54. Salehi SA, Koski T, Ondra SL: Spinal cord compression in beta-thalassaemia: case report and review of the literature. *Spinal Cord* 2004, 42: 117-123
55. Shin KH, Sharma S, Gregoritch SJ, Lifeso RM, Bettigole R, Yoon SS: Combined radiotherapeutic and surgical management of a spinal cord compression by extramedullary hematopoiesis in a patient with hemoglobin E beta thalassaemia. *Acta Haematol* 1994, 91: 154-157
56. Singhal S, Sharma S, Dixit D, et al: The role of radiation therapy in the management of spinal cord compression due to extramedullary hematopoiesis in thalassaemia. *J Neurol Neurosurg Psychiatry* 1992, 55: 310-312
57. Singounas EG, et al: Paraplegia in a pregnant thalassaemic woman due to extramedullary hematopoiesis: successful management with transfusions. *Surg Neurol* 1991, 36: 210-215
58. Sorsdahl OS, Taylor PE, Noyes WD: Extramedullary hematopoiesis, mediastinal masses, and spinal cord compression. *JAMA* 1964, 189: 343-347
59. Tai SM, Chan JSH, Ha SY, Young BWY, Chan MSM: Successful treatment of spinal cord compression secondary to extramedullary hematopoietic mass by hypertransfusion in a patient with thalassaemia major. *Ped Hematol & Oncol* 2006, 23: 317-321
60. Tan TC, Tsao J, Cheung FC: Extramedullary hematopoiesis in thalassaemia intermedia presenting as paraplegia. *J Clin Neurosci* 2002, 9: 721-5
61. Turgut B, Pamuk GE, Vural O, Demir M, Unlu E, Celik H: An interesting presentation of intrathoracic EMH in a patient with thalassaemia intermedia. *Clin Lab Haematol* 2003, 25: 409-11
62. Tze-Ching Tan, Tsao Joanne, Fung-Ching Cheung: Extramedullary haemopoiesis in thalassaemia intermedia presenting as paraplegia. *J Clin Neuroscience* 2002, 9(6): 721-725