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Prognosis of cervical spinal cord injury in correlation with magnetic resonance imaging

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Magnetic resonance (MR) images of 18 patients with a cervical spinal cord injury were analysed for prognostic signs of paralysis. Serial MR images were obtained within 48 hours (acute stage), then 2 weeks (subacute stage) and an average of 12 months (range 6–24 months) after injury. The patterns of signal intensity in the acute stage were divided into two types, slightly-low/low (SL/L) type and slightly-low/high (SL/H) type on T1-weighted images (T1WI) and T2-weighted images (T2WI). The patterns in the subacute stage were divided into two types, high/high (H/H) type and normal/high (N/H) type on T1WI and T2WI. Six patients showed SL/L type in the acute stage and H/H type in the subacute stage. Five of the patients had a paralysis of grade A and one of grade B at admission which remained unchanged after treatment. One patient showed SL/H type in the acute stage and H/H type in the subacute stage. The patient had a paralysis of grade A that improved to no more than grade B. The remaining 11 patients showed SL/H type in the acute stage and N/H type in the subacute stage. Their paralysis was from grade B to D at admission and grade D or E at the follow up. The signal intensity of SL/L type in the acute stage and H/H type in the subacute stage are bad prognostic signs.

Keywords: cervical spinal cord injury; magnetic resonance imaging; prognosis.

Introduction

The prognosis of acute spinal cord injury has been predicted to some extent by magnetic resonance imaging (MRI), which reflects histopathological changes of the intramedullary lesion.[1–3] Many investigators have considered a low signal intensity to be due to the presence of deoxyhaemoglobin, a product of haemoglobin metabolism, on T2-weighted images in the acute stage as a result of haemorrhage, a bad prognostic sign.[4–9] However, the signal intensity changes with further metabolism of haemoglobin in the course of time. Therefore, other signs of prognosis of a spinal cord injury based on MRI are expected and require searching. We performed MR imaging serially from the acute to chronic stage in order to search for prognostic signs of paralysis due to a cervical spinal cord injury.

Materials and methods

Eighteen patients with an acute cervical spinal cord injury were studied in this series. There were 14 males and four females. The age at injury ranged from 12 to 74 years (mean 48 years). Paralysis at admission was graded A in six patients, B in two, C in two, and D in eight according to the Frankel's grading system. Seven patients had a fracture-dislocation, while 11 showed no radiological abnormalities (SCIWORA). Five of the seven patients with a fracture-dislocation were treated by open reduction and spinal fusion, and the remainder were conservatively treated by skull traction and steroid therapy. All 11 patients with SCIWORA were treated conservatively.

The first MRI was taken within 3 to 48 hours (mean 23 hours) in the acute stage after injury, and the second MRI after 2 weeks in the subacute stage. The follow up MRI was obtained after 12 months on average (range, 6–24 months) in the chronic stage after injury. The images were analysed and correlated to the improvement of paralysis.

Images were obtained with a 1.5 tesla superconductive MR scanner with a surface coil. T1-weighted images (T1WI) were obtained with echo time (TE) of 20 ms and pulse repetition time (TR) of 500 ms, and T2-weighted images (T2WI) with TE of 80 ms and TR of 2000 to 3000 ms with spin echo (SE) sequences. The slice thickness was 5 mm.

Results

Patterns of signal intensity of the injured cervical spinal cord and severity of paralysis

MR images in the acute stage were divided into two types; slightly-low signal intensity on T1WI and low signal intensity surrounded by a zone of high signal intensity on T2WI (SL/L type), and slightly low on T1WI and high on T2WI (SL/H type). Six patients showed SL/L type and twelve, SL/H type.

MR images in the subacute stage were divided into two types; high signal intensity on both T1WI and T2WI (H/H type), and normal on T1WI and high on T2WI (N/H type). Seven patients showed H/H type and 11 N/H type.

MR images in the chronic stage at the follow up were divided into three types; low signal intensity on T1WI and high on T2WI (L/H type), normal on T1WI and high on T2WI (N/H type) and normal on both T1WI and T2WI (N/N type). Twelve patients showed L/H type; four, N/H type; and two, N/N type.

Changes of signal intensity after the injury (Fig 1)

The changes of signal intensity on serial MR images obtained in the acute to chronic stages showed five patterns as follows. All six patients of SL/L type in the acute stage showed H/H type in the subacute stage and

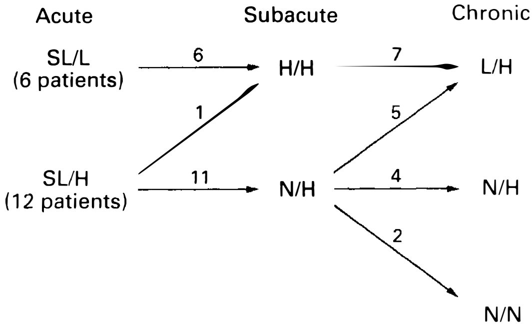


Figure 1 Changes of signal intensity after the injury. SL/L: slightly-low signal intensity on T1WI and low signal intensity surrounded by a zone of high signal intensity on T2WI. SL/H: slightly-low signal intensity on T1WI and high on T2WI. H/H: high signal intensity on both T1WI and T2WI. N/H: normal signal intensity on T1W1 and high on T2WI. L/H: low signal intensity on T1WI and high on T2WI. N/N: normal intensity signal on both T1W1 and T2WI.

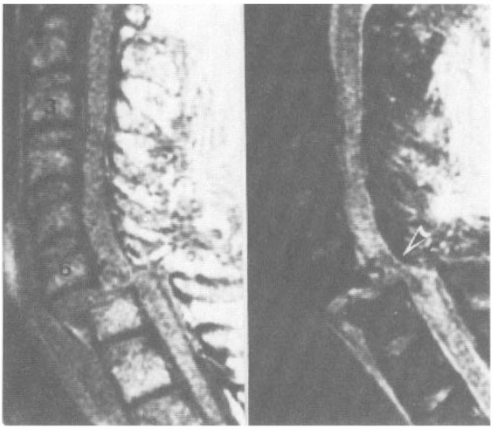
L/H type in the chronic stage (Fig 2). The 12 patients of SL/H type in the acute stage showed four different changes of signal intensity. One revealed H/H type in the subacute stage and L/H type in the chronic stage. Five showed N/H type in the subacute stage and L/H type in the chronic stage. Four disclosed N/H type in the subacute stage and N/H in the chronic stage. Two showed N/H type in the subacute stage and N/N type, normal signal intensity, in the chronic stage. In this normalised group, the high signal intensity on T2WI in the acute and subacute stages had its indistinct margin.

Correlation between changes of signal intensity and improvement of paralysis (Fig 3)

Out of the six patients of SL/L type in the acute stage, five had grade A paralysis and one had grade B paralysis. None improved.

The single patient who showed SL/H type in the acute stage, H/H type in the subacute stage and L/H type in the chronic stage had had grade A paralysis at admission. This patient improved to no more than grade B.

a



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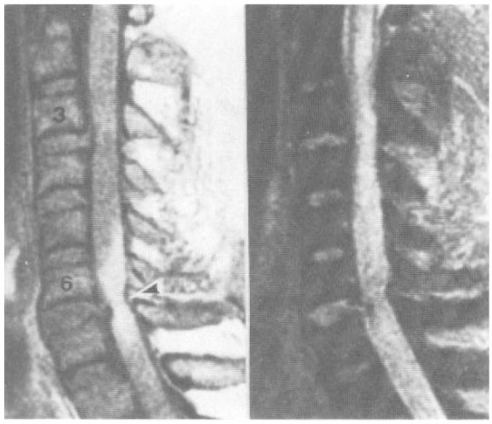

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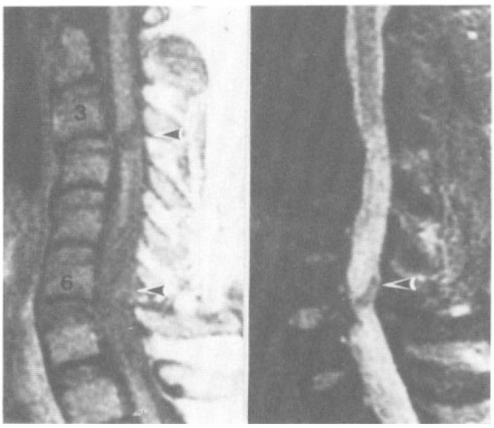

Figure 2 A 49 year old man had cervical spinal cord injury due to bilateral dislocation at C6–7 combined with subluxation at C3–4. Paralysis was graded A in the acute stage and was unchanged in the chronic stage. (a) MR images of SL/L type 24 hours after injury. Left: slightly-low signal intensity at C3–T1 on T1WI. Right: low signal intensity at C6–7 with a surrounding zone of high signal intensity at C3–T1 on T2WI (arrow). (b) MR images of H/H type 2 weeks after injury. Left: slightly high signal intensity at C3–4 and markedly high at C5–7 on T1WI (arrow). Right: high signal intensity at C1–T2 on T2 on T2WI. (c) MR images of L/H type 1 year after injury. Left: low signal intensity at C3–4 and C5–7 (arrow) on T1WI. Right: high signal intensity at C3–T1, with a core of low signal intensity at C6–7 (arrow).

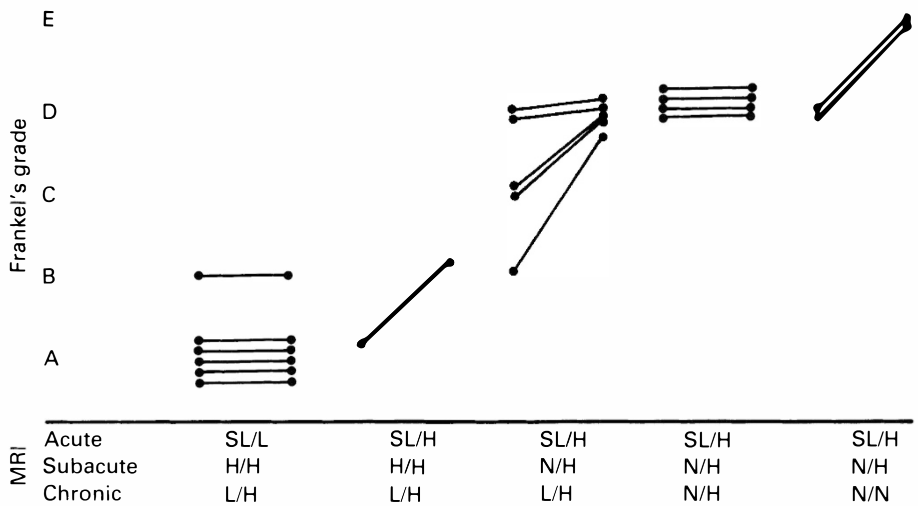

Figure 3 Correlation between changes of signal intensity and improvement of paralysis.

The five patients who showed SL/H type in the acute stage, N/H type in the subacute stage and L/H type in the chronic stage had had grades B–D paralysis at admission. Three of the patients improved, by one to two grades. Paralysis in these patients at follow up was grade D.

All four patients who showed SL/H type in the acute stage, N/H type in the subacute stage and N/H type in the chronic stage had had grade D paralysis at admission. They remained at grade D although a little improvement was observed.

The two patients who showed SL/H type in the acute stage, N/H type in the subacute stage and N/N type in the chronic stage had had grade D paralysis at admission. They recovered completely to grade E.

Discussion

The prediction of the fate of an injured spinal cord has been performed based on neurological findings alone. No improvements are expected in a patient with a complete paralysis even after the bulbocavernous or anal reflexes have recovered or after 24 hours have passed.[10] However, it is difficult to predict the prognosis of a patient in spinal shock or with an incomplete paralysis.

The signal intensity on MR images, which reflects histopathological changes such as oedema and haemorrhage of the injured spinal cord,[1–3] may foretell the outcome of the paralysis. A low signal intensity on T2WI of the injured spinal cord in the acute stage has been considered to be a bad prognostic sign.[4–9] All six patients with a low signal intensity on T2WI had a poor improvement of paralysis in this study.

Gomori[11] speculated that a low signal intensity on T2WI reflects deoxyhaemoglobin in an acute stage of haematoma of the human brain. Deoxyhaemoglobin, a product of metabolism, markedly shortens T2 relaxation time. This physical characteristic of deoxyhaemoglobin leads to a low signal intensity on T2WI in high magnetic fields. The low signal intensity on T2WI in the acute stage of a spinal cord injury in this study is also considered to reflect deoxyhaemoglobin in an intramedullary haemorrhage.[6,12]

Every signal intensity of SL/L type observed in the acute stage of six patients changed to H/H type in the subacute stage. In addition, the signal intensity of SL/H type in the acute stage changed to H/H type in the subacute stage in one patient. The patient also had little improvement of paralysis. The high signal intensity on T1WI in the subacute stage is also a bad prognostic sign. No report has described this characteristic sign in the injured spinal cord to date. Gomori[11] described this high signal intensity on T1WI in the subacute stage of brain haemorrhage as reflecting methaemoglobin, a further product of haemoglobin metabolism. A high signal intensity on T2WI reflects a combination of methaemoglobin and oedema. The signal intensity of H/H type in the injured spinal cord in this study may reflect a production of methaemoglobin in haemorrhage.

Paralysis in the 11 patients who showed SL/H type in the acute stage and N/H type in the subacute was incomplete and graded B–D at admission. The paralysis improved to grade D in nine patients and recovered to grade E in two. The signal intensity of SL/H type in the acute stage is considered to be a sign of good prognosis with the exception of one case with a change to H/H type in the subacute stage. The signal intensity of N/H type in the subacute stage is also a good prognostic sign.

Conclusions

1 Serial MRI in the acute and subacute stages of a cervical spinal cord injury is recommended for the prediction of prognosis since images change in the course of time.
2 The low signal intensity on T2WI in the acute stage and high signal intensity on T1WI and T2WI in the subacute stage are signs of poor prognosis.
3 The signal intensity of SL/H type in the acute stage and N/H type in the subacute stage are signs of good prognosis.

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