Peer reviewed article

CT and MR imaging of chronic subdural haematomas: a comparative study

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Summary

Questions under study/principles: This study was designed to compare CT and MR appearances of chronic subdural haematomas as well as CT- and MR-guided measurements of haematoma thicknesses.

Methods: CT and MR images of 48 chronic subdural haematomas of 34 patients were reviewed retrospectively. The thickness measurements and imaging characteristics of haematomas were compared.

Results: Levelling was observed in 25% of haematomas, and most of them (60%) had intrahaematomal membranes. All membranes could be delineated by MR imaging, whereas only 27% were defined by CT. Mixed density (52%) and T1 hyperintensity (59%) were commonly observed in membraned haematomas, but the difference was not statistically significant. Haematomas were measured significantly thicker on MR images. All patients had been treated with burr-hole craniotomy and irrigation.

Conclusions: MR imaging is more sensitive than CT in determining the size and internal structures of chronic subdural haematomas.

Key words: chronic subdural haematoma; computed tomography; magnetic resonance imaging; haematoma thickness; intrahaematomal membrane

Introduction

Chronic subdural haematoma (CSDH), which generally occurs in older patients, is one of the most frequent clinical entities encountered in neurosurgery departments. With early diagnosis and adequate surgical treatment the prognosis is favourable. Computed tomography (CT) remains the most important imaging method in the initial evaluation of CSDHs [1]. It is a faster, cheaper and more available technique than magnetic resonance (MR) imaging. However, MR imaging provides more precise localisation and determination of the extent of haematoma and its mass effect on adjacent structures [2]. MR imaging is more advantageous in the case of isodense and bilateral CSDHs [2, 3].

CT and MR imaging of CSDHs detect various patterns, which can be attributed to many factors including the age of the haematoma, the presence of rehaemorrhage and the haematocrit status of the patient [4–6]. In this study 48 haematomas in 34 patients were evaluated by determining CT density and MR intensity characteristics and internal structures such as intrahaematomal membranes and layering. The thickness of each haematoma was measured on CT and MR images and the measurements obtained by these two methods were compared. We also attempted to determine whether there was any difference in duration of symptoms and hospital stay of patients with haematomas showing various MR characteristics.

No conflict of interest in relation to this article.

Abbreviations

CSDH	Chronic subdural haematoma
CT	Computed tomography
MR	Magnetic resonance
T1W	T1-weighted
T2W	T2-weighted

Materials and methods

From July 2002 to October 2007, 34 adult patients who had both CT and MR evaluation of a symptomatic CSDH were included in the study. CT and MR images together with clinical data concerning aetiology, symptoms and signs, diagnosis and therapy of all 34 patients (23 males and 11 females) were retrospectively obtained from documents of the Department of Neurosurgery of our institution. Ethics committee approval or informed consent from patients was not required for this retrospective study.

Forty-eight haematomas of 34 patients, age range 17–93 (mean 60.56 years), were included in the study: 20 patients had unilateral and 14 patients bilateral haematomas. Of the 34 patients 19 (56%) had a history of head trauma, which in all cases, except for two motor vehicle accidents, was minor. CT was performed at initial evaluation and MR imaging within 0–7 days with a mean of 1.88 days after CT scans. The capsule and chronic natures of subdural haematomas were confirmed by surgery in all patients.

Imaging was performed on high resolution spiral CT systems and on 1 Tesla or 1.5 Tesla MR scanners. All MR studies included a transverse and sagittal T1-weighted (T1W) spin-echo sequence (400–600/15–20 [repetition time/echo time]) and a transverse or coronal T2-weighted (T2W) spin-echo sequence (2500–4000/90–105 [repetition time/echo time]) using 5 mm slice thickness and 1 mm gap. Slice thickness of CT images was 10 mm without gap. All transverse CT and MR images were obtained parallel to the vertex with analogous angulations.

MR images were evaluated two weeks after CT characteristics of haematomas were determined and all CT-guided measurements were completed.

CSDHs were classified into 4 groups according to their CT density characteristics: low, high and mixed density, and isodense (where the density of the haematoma appears equal to that of the grey matter of the brain). They were also classified into 3 groups according to their MR intensity characteristics on T1W images: low, high and mixed intensity. Levelling and membranes were searched on CT and MR images. CT density (low, high and mixed density, and isodensity) and MR intensity (low, high and mixed intensity) characteristics of haematomas with and without membranes were compared by Chi-square test.

Students' t-test for independent samples was used to compare time from onset of haematoma symptoms of various MR characteristics, either with intrahaematomal membranes or not, hyperintense (including mixed intensity haematomas which were predominantly T1 hyperintense) or hypointense on T1W images. The mean hospital stay of patients with membraned and non-membraned haematomas was also calculated.

Two radiologists checked consecutive transverse slice positions of CT and MR images before performing measurements to make sure that slice positions were comparable. On CT and MR images the levels representing the largest amount of haematoma were determined on axial images, and the maximum thickness of each haematoma was measured at these levels (fig. 1). Haematomas could be definitely differentiated from subarachnoid space and other possible collections on T1W images. Therefore, maximum thickness of each haematoma was measured on axial T1W MR images. Measurements were performed from the central part of the crescent-shaped haematoma vertical to the convexity of the calvarial bones. The thickness of each haematoma was measured manually by means of scale bars on the CT and MR images. The measurements were obtained with the consensus of two radiologists. Students' t-test for pair-wise comparison was used to compare the measurements guided by CT and MR images. The values were expressed as the mean ± standard deviation.

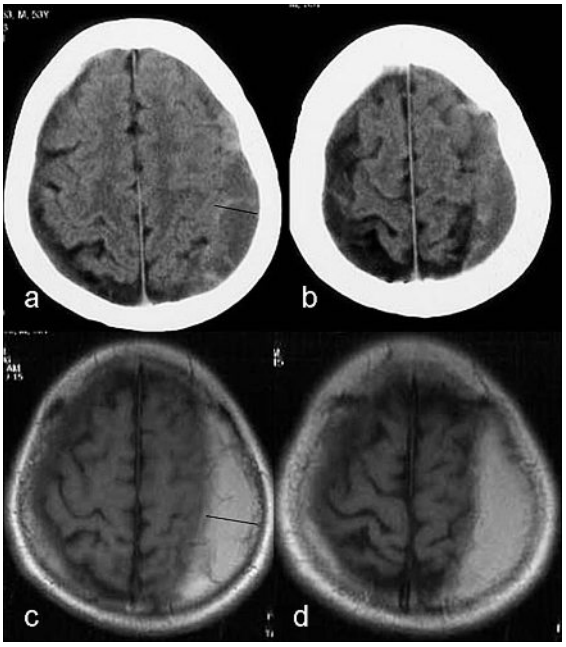


Figure 1

Difference of haematoma thickness on CT and MR imaging.
a, b. Haematoma thickness measurement on consequent CT scans.
c, d. Haematoma thickness measurement on consequent transverse T1W MR images of the same patient. Black line represents the thickness measurement performed from the central part of the crescent-shaped haematoma vertical to the convexity of the parietal bone. Note that haematoma appears larger on MR images.

Results

All patients were treated by burr-hole craniotomy. The capsule and chronic natures of subdural haematomas were confirmed by surgery in all 48 haematomas. Membranes were observed in 29 haematomas of 21 patients. The aetiology was identifiable in 19 patients (56%) who had a history of head trauma. Except for two motor vehicle accidents, all the head traumas were minor. The leading symptom was headache. Confusion, hemiparesis and seizures were other symptoms. Days after trauma or onset of symptoms varied from 14 to 72 days with a mean of 33.3 days.

The mean haematoma thicknesses obtained by CT and MR images are summarised in table 1. The difference between measurements of haematoma thickness guided by MR imaging (mean 21.00 ± 9.09) and CT scans (mean 17.15 ± 8.62) was statistically significant ($t = 11.225$; $p < 0.05$).

Table 1

Measurements of haematoma thicknesses.

Imaging method	N (number of haematomas)	Mean haematoma thickness (mm)
CT	48	17.1458
MR	48	21.0000

Table 2

Distribution of haematomas according to CT density characteristics.

CT density	Number of haematomas
Hypodense	18
Isodense	10
Mixed density	19
Hyperdense	1

Table 3

Distribution of haematomas according to MR intensity characteristics.

MR intensity	Number of haematomas
Hypointense	10
Mixed Intensity	14
Hyperintense	24

There was a high correlation between CT and MR measurements of haematoma thicknesses ($p < 0.05$).

Distribution of haematomas according to their CT and MR imaging characteristics is shown in tables 2 and 3. Eighteen haematomas (38%) were hypodense and 10 (21%) were isodense on CT scans. In addition, 19 (40%) haematomas were mixed density and only 1 (2%) was hyperdense. The CT appearances of hypodense, isodense and hyperdense haematomas are shown in figure 2. All mixed density haematomas were either isodense or hypodense and contained hyperdense areas.

Only 10 (21%) of the 48 haematomas were hypointense on T1W MR imaging. Half of CSDHs (n = 24) were hyperintense and 14 (29%) were mixed intensity (fig. 3). All mixed intensity haematomas were predominantly hyperintense. In all, 79% of haematomas were hyperintense.

Isodense haematomas were diagnosed with the aid of two findings on CT: (1) sulcal effacement, (2) midline shift and mass effect on the ventricles. However, all isodense haematomas were clearly delineated on MR images (fig. 4).

All mixed density haematomas on CT were ei-

Figure 2

CT density patterns. a. Hypodense subdural haematoma. b. Isodense subdural haematoma. c. Hyperdense subdural haematoma (arrow). d. Mixed density left frontoparietal haematoma with levelling. e. Mixed density haematoma with hyperdense component (black arrow), and intrahaematomal membrane (white arrow).

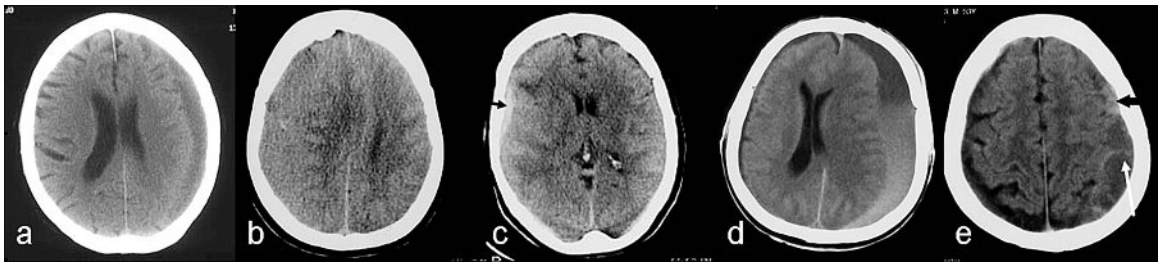


Figure 3

MR imaging characteristics. a. Hypointense haematoma. b. Hyperintense haematoma. c. Mixed intensity left frontoparietal haematoma with loculations and membranes. There is also a small right parietal hyperintense haematoma. d. Bilateral mixed intensity haematomas with levelling.

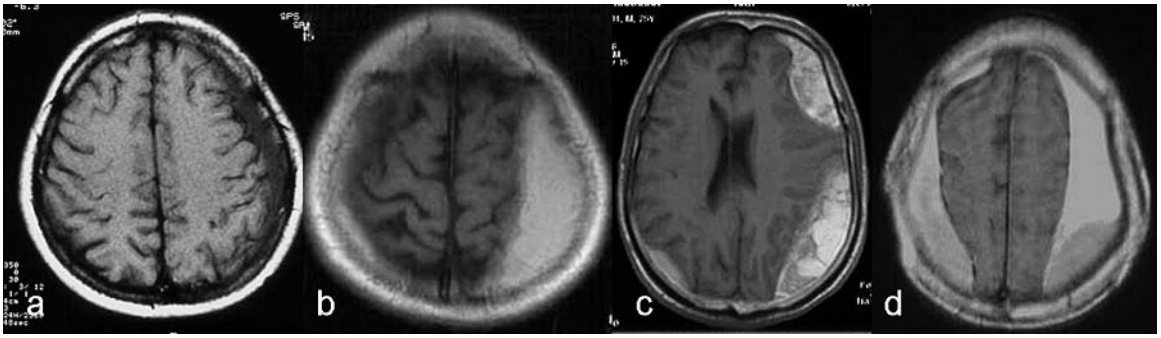
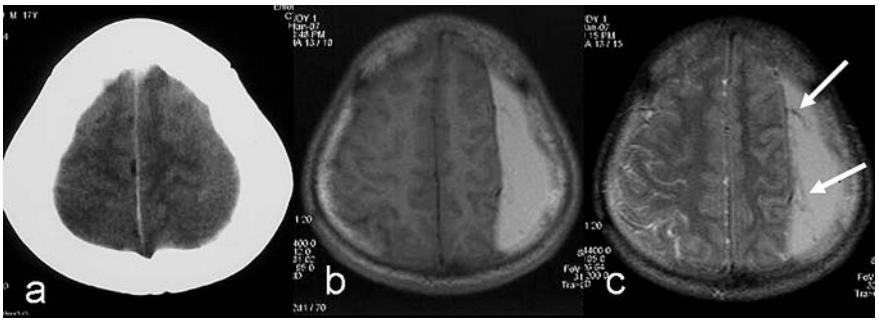


Figure 4

Comparison of extent of haematoma and determination of membranes on CT and MR imaging.
a. Isodense haematoma is barely recognised on CT with the aid of sulcal effacement.
b. Hyperintense haematoma with thin membranes (white arrows) is shown on T1W image.
c. Membranes (white arrows) are clearly discernible on T2W image.



ther layered or contained intrahaematomal membranes (fig. 2). Most of the haematomas with membranes were mixed density on CT scans. Membrane was discernible clearly in 3 of these mixed density haematomas. When CT scans were compared with MR images, some hyperdense areas of mixed density haematomas were in agreement with the capsule and membranes on MR images.

Levelling was observed in 12 haematomas (25%) on both CT and MR images. Intrahaematomal membranes were surgically confirmed in 29 CSDHs (60%). Only 8 haematomas (27%) had membranes on CT scans, whereas all membranes were recognisable on MR images, especially on T2W images (fig. 4).

Haematomas with membranes showed all types of characteristics both on CT and MR images. However, mixed density on CT (52%) and high intensity on MR (59%) were common observations. Chi-square test was applied to compare CT density and MR intensity of haematomas with or without membranes; however, no relationship was found statistically ($p > 0.05$).

There was no statistically significant difference between duration of symptoms in hyperintense haematomas (mean 34.4 ± 10.7 days) and hypointense haematomas (mean 28.5 ± 7.1 days) on T1W images. Duration of symptoms did not differ significantly in haematomas with membranes (mean 34.4 ± 11.9 days) and without membranes (mean 31.3 ± 7.6 days) either.

All patients had similar outcome without early serious complications, except for one patient with acute myeloid leukaemia who died on the fifth day of hospitalisation due to adult respiratory distress syndrome. Hospital stay was 3–7 days.

Discussion

In this study we observed that various density and intensity patterns of CSDHs can be detected with CT and MR imaging. Unlike chronic intraparenchymal haematomas, mixed density on CT and T1 hyperintensity are common in CSDHs. Either layering or membranes are observed in mixed density haematomas. Layering can be observed both on CT and MR images, whereas most of the membranes, all of which are clearly delineated on MR imaging, cannot be recognised on CT scans. MR is superior to CT when detecting membranes in CSDHs. We also found that haematomas appeared thicker on MR images compared to CT. We therefore suggest that the extent and internal structures of CSDHs can be more precisely evaluated by MR imaging, which provides high-resolution images and better delineation of haematoma margins.

The capsule of CSDH consists of the outer membrane adhering to the dura mater and the inner membrane on the arachnoid side. The vessels of the capsule, which have a marked proliferation potential and a fragile nature, are the most important factor for the development of CSDH [7]. Repeated microhaemorrhages from the neocapillary network in the outer membrane of CSDH, and increased fibrinolytic activity of fibrinogen degradation products, result in large CSDHs [1]. Thrombomodulin expressed on the sinusoidal vessels of the outer membrane in CSDHs inhibits the blood coagulation system in the haematoma. Excessive activation of both the coagulation and fibrinolytic systems and high expression of tissue-type plasminogen activator in haematomas are proposed as possible explanations for the failure of haematomas to coagulate [8–10]. Thus, CSDHs grow gradually without coagulating.

The pathogenesis of CSDHs with excessive activation of both the coagulation and fibrinolytic systems results in complex imaging patterns. CSDHs can be low and high density, isodense or mixed density on CT. MR imaging appearances are more complex [11, 12]. Acute and subacute subdural haematomas follow signal intensity patterns of intraparenchymal brain haemorrhage on MR imaging, but they differ in the chronic phase due to absence of blood–brain barrier in the subdural space [5]. The propensity of CSDHs for repeat haemorrhage further complicates the CT density and MR signal intensity patterns. The phenomenon of repeated haemorrhage is characterised by layering effects and membranes as well as more frequent haemosiderin deposition [5].

On MR, the haematocrit, methaemoglobin and free Fe^{3+} levels are three major factors causing prominent shortening in relaxation times and thus high intensity on T1W imaging [13]. T1 shortening, which results with hyperintensity, generally represents methaemoglobin, the typical component of subacute haematoma [13–15]. The CSDH may be slightly hypointense to isointense relative to grey matter on short repetition time/echo time (TR/TE), corresponding to T1W, images. Fobben et al. postulate that these signal intensity changes are the result of a decrease in concentration of free methaemoglobin either by dilution, absorption and/or degradation [5]. However, persistence of high signal intensity, typical of the subacute intracranial haematomas [15], beyond its expected time interval is a common observation, which is probably due to repeated haemorrhage.

A CSDH is characterised by well formed inner and outer membranes and, regardless of the time interval when the capsule is confirmed surgically, the haematoma should be regarded as chronic [16]. Methaemoglobin, and thus T1 hyperintensity, may be the result of either a short time interval from the onset of haemorrhage or of

rehaemorrhage. In all, 79% of haematomas in our study were predominantly hyperintense on T1W images. Hosoda et al. reported 18 CSDHs, 12 (67%) of which were hyperintense on T1W images [2]. Another study by Tsutsmi et al. showed that 164 (71%) of 230 CSDHs were hyperintense and mixed intensity [17]. These previously published studies and our study support the hypothesis that although various intensity patterns are detected with MR imaging, most of the CSDHs are predominantly hyperintense on T1W images.

Layering type and mixed density haematomas have a stronger tendency to rebleed [18]. The study by Lee et al. [19] demonstrated that 67% of mixed density CSDHs required reoperation. Tsutsumi et al. suggested that T1W MR imaging was useful in predicting the propensity of CSDHs to recur [17]. They showed that high-intensity haematomas on T1 images had a lower recurrence rate. However, Havenbergh et al. suggested that CT findings had no influence on the patients' outcome [20]. In this study we did not observe any relationship between the prognosis and CT and MR imaging characteristics of CSDHs either. The absence of recurrences in this study may be due to the small number of patients or to the absence of long-time follow-up. Whether CT and MR imaging findings are important indicators of prognosis is still unclear.

Despite general agreement concerning the indication for surgical treatment, the extent of surgery is controversial [12, 19, 21–24]. Some authors postulate that a small craniotomy can be preferred for thick-membraned, loculated or multilayered haematomas and solid haematomas with rehaemorrhage, whereas burr hole craniotomy or twist drill craniotomy is suitable for more homogeneous-appearing haematomas [19, 25]. However, others believe that less invasive procedures are adequate [12, 19, 24]. It is known that some loculated haematomas with membranes recur and require craniotomy, and MR imaging is useful in predicting the propensity of CSDHs to recur [17]. This study shows that MR imaging is superior in delineating membranes of CSDHs. A small craniectomy instead of less invasive procedures may be preferred when MR shows thick membranes. Thus, MR imaging may influence the type of surgery.

An important limitation of our study is that imaging of all patients could not be performed on the same CT and MR scanners. CT and MR images could not be obtained simultaneously either. MR images were obtained 0–7 days after CT scanning. In the time period between CT and MR scans the clinical status of the patients remained the same, and rebleeding was not considered. When the long period from onset of symptoms or trauma to CT scan (14–72 days) is taken into account, this delay is not expected to influence the appearance of haematoma on MR imaging.

Slice position was an important factor that could influence the measurement results. All transverse CT and MR images were obtained parallel to the vertex with similar angulations, and two radiologists checked consecutive slice positions to make sure that slice positions were comparable if not identical. Slice thickness of CT and MR scans was not identical either. However, since measurements were performed on tranverse plane vertical to the convexity of the calvarial bones, slice thickness has little or no influence on haematoma thickness.

The diagnosis of CSDH is generally established by CT, which is a very fast scanning method but has some important limitations. Exclusion of other subdural collections such as effusions and hygromas may be difficult in the case of hypodense subdural haematomas [5, 26]. Isodense haematomas and small amounts of subdural collections are barely recognisable on CT [6, 16, 27], whereas they are clearly discerned on MR images [2, 28]. Subdural hygroma or effusions can also be easily diagnosed by MR imaging [5, 29]. Previously published studies showed that MR imaging is superior to CT in diagnosing small CSDHs [25, 30, 31]. It is also difficult to delineate haematoma margins of isodense haematomas on CT, especially when they are bilateral [30]. In this study we evaluated 29 isodense and mixed density haematomas, and we also observed that it was difficult to delineate the exact margins of most of these haematomas on CT. We observed that haematoma margins were clearly delineated with MR, and haematomas appeared thicker on MR. We also showed that all membranes could be determined by MR imaging, whereas only 27% of them were delineated by CT. MR is therefore superior to CT when evaluating CSDHs.

CT is adequate for diagnosis when the extent of CSDH can be clearly shown and other subdural collections can be excluded. Since the thickness of a haematoma is not very important when planning surgery, and most patients can be treated with less invasive procedures, MR imaging is not essential. However, a small craniotomy may be preferred for thick-membraned, loculated or multilayered haematomas, and, since most membranes could not be identified on CT, MR imaging is useful. The inner structures of the haematoma can change the plan of surgery. We therefore suggest that if the clinical status of the patient is not urgent, MR imaging, when available, is useful in delineating the exact margins of haematomas and determining internal structures of haematomas.

Conclusions

Various density and intensity patterns are detected with CT and MR imaging, but most CSDHs are mixed density and predominantly hyperintense on T1W images.

MR imaging is more accurate than CT when delineating the extent and determination of membranes of CSDHs, and with it hypodense CSDHs can be differentiated from other subdural collections. Small and isodense CSDHs are better evaluated by MR. Mixed density CSDHs on CT are generally layered, and membraned haematomas and the internal structures can be clearly shown by MR imaging, thus possibly changing the treatment strategy.

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