ANALYSIS OF PEDIATRIC SUBDURAL EMPYEMA OUTCOME IN RELATION TO COMPUTERIZED TOMOGRAPHY BRAIN SCAN

Ahmad Razali Md Ralib,[1] Abdul Rahman Mohd Ariff[1], Ibrahim Lutfi Shuaib[1], NN Naing[2], P Jain George[3] and Jafri Malin Abdullah[3]

[1]Department of Radiology, [2]Unit of Biostatistics and Research Methodology, [3]Department of Neurosciences, Universiti Sains Malaysia Health Campus, Kelantan, Malaysia

Abstract. A cross-sectional study was conducted to predict the outcome in patients with subdural empyema, using initial and post-treatment CT scan brain parameters. Data collection was done on those children who were diagnosed to have subdural empyema by CT scan of the brain with contrast, who underwent burrhole evacuation, from February 2000 until April 2002. Numerous factors, such as coma or loss of unconsciousness at diagnosis, age, types of antibiotic, microbiology, extension of empyema, associated cerebral infarction and ventriculitis, were analyzed. Poor prognosis was associated with loss of consciousness, and hypodensity by CT scan at presentation ($p < 0.005$). Patients with an extensive subdural empyema will have a good outcome if they are treated early and aggressively with antibiotics and burrhole evacuation.

INTRODUCTION

Subdural empyema, which is a collection of pus within the potential space between the dura and arachnoid mater is a well-known life-threatening condition. It accounts for about 30% of intracranial infections (Blaquiere, 1983). Before the era of antibiotics, this condition was usually fatal. From 1950 to 1975, mortality was about 25 to 40% (Mauser *et al*, 1987). However, with the advent of computed tomography (CT) scan and improvement in antibiotics and intensive care facilities, mortality has improved to about 10 to 20% (Bannister *et al*, 1981; Mauser *et al*, 1987).

It is usually caused by neglected paranasal sinusitis (usually frontal sinusitis), meningitis, otitis media, and post-trauma. The major pathogens include Streptococci, anaerobic organisms, Staphylococcci, *Haemophilus influenzae* and *Proteus mirabilis*. Sterile culture was also common. (Nathoo *et al*, 1999).

Magnetic resonance imaging (MRI) has become the modality of choice in evaluating subdural empyema, because it is more sensitive than a CT scan, it can differentiate subdural from epidural empyema, provide better characterization of the extraaxial fluid, and detect concomitant parenchymal alterations (Weingarten *et al*, 1989). Several authors reported failures of CT scans to detect subdural empyema (Dunker and Khankoo, 1981; Baum and Dillon, 1992). In Southeast Asia, the CT scan is still the modality of choice especially in comatose or critically ill patients, where MRI is not economic or practical.

Subdural empyema is a neurosurgical emergency, requiring immediate neurosurgical drainage either by craniotomy, or burrhole with drainage together with debridement or removal of the primary source of infection.

No study has clearly addressed the role of the initial CT scan as an indicator of patient survival. This study was conducted to predict the outcome in patients with subdural empyema, using initial and post-treatment brain CT scan parameters.

MATERIALS AND METHODS

Patient selection

This cross-sectional study involved all children diagnosed with subdural empyema by brain CT scan with contrast who underwent burrhole evacuation from February 2000 until April 2002.

Correspondence: Dr Jafri Malin Abdullah, Department of Neurosciences, Universiti Sains Malaysia Health Campus, 16150 Kubang Kerian, Kelantan, Malaysia.
Tel: 609-7664240; Fax: 609-7648613
E-mail: unitneurosainsppspusm@yahoo.com

Patients who were older than 12 years with a history of neurological disease, and those who did not undergo surgery, were excluded from the study.

After completion of 6 weeks of antibiotics, a second CT scan of the brain with contrast was performed. Two radiologists who were blinded to the history and outcome of the patients, reviewed the CT scan films.

The initial CT scan was done to see the following features: location of the subdural empyema, subdivided into whether it was over the convexity (frontal, temporal, parietal and occipital) or parafalcine region, thickness of the subdural empyema at the largest vertical distance between the cortex and the tabula interna (in millimeters) (Zumkeller *et al*, 1996), midline shift (in millimeters), estimated volume of subdural empyema (Kido *et al*, 1992), presence of hydrocephalus (Rao, 1999), presence of hypodense areas within the brain parenchyma (single or multiple), presence of subdural abscess or empyema (Broderick *et al*, 1993), and enhancement on IV contrast, either only the empyema or involving the ventricles, basal cistern and brain parenchyma.

The CT scan 6 weeks' post-treatment was done to see the following features: presence of any residual subdural empyema, thickness of the residual subdural empyema at the largest vertical distance between the cortex and the tabula interna, midline shift, estimated volume of the subdural empyema (Kido *et al*, 1992), presence of hydrocephalus, presence of cerebral atrophy, presence of hypodense areas within the brain parenchyma (single or multiple), presence of epidural abscess/empyema and enhancement on IV contrast, either only the empyema or involving the ventricles, basal cistern and brain parenchyma. All patient particulars were recorded from case notes, *ie* demographic data, history of illness and physical examination findings, particularly onset of illness before initial CT brain (days), seizures (whether focal, generalized, or none), hemisyndromes, and level of consciousness which was defined using the neurological grade on admission and mortality used by Bannister *et al* (1981). For purposes of statistical analysis, level of consciousness was classified into two groups. Group A consisted of grades I and II. Group B consisted of grades III and IV. The grades were defined as: grade I (alert and orientated), grade II (drowsy and disorientated), grade III (response to stimulation), and grade IV (no purposeful response, even to pain).

Other information collected about the patients were: possible source of infection-sinusitis (Kronomer and McAlister, 1997), otitis media (Damoiseaux *et al*, 2000), meningitis (Grimwood *et al*, 1995), recent intracranial surgery-bacteriology [blood culture (if growth, the offending organism], cerebrospinal fluid culture: from lumbar puncture or surgery (if growth, the offending organism), surgical treatment, amount of pus drained (mls), hydrocephalus treatment (none, EVD, Rickhams, both) and revision of operation (none, single, more).

Preoperatively, all patients were treated with antibiotics, which continued for at least 6 weeks. Final outcome was assessed at the time of discharge, after completion of intravenous antibiotics and during the follow-up period in the outpatient neurosurgical clinic. Factors that were assessed for final outcome were any seizures (Dichter, 1994), focal or generalized seizures, hemisyndrome improvement and functional status at discharge and follow-up in the outpatient neurosurgical clinic. Functional status was categorized as group 1 (excellent), group 2 (neurologically handicapped), group 3 (severely neurologically handicapped), and group 4 (deceased) (Bok and Peter, 1993).

Statistical analysis

Statistical analysis was done using SPSS computer software version 10.0. Sociodemographic data were analyzed using descriptive analysis. The patients were grouped by functional status at outcome as good, poor, or death. The associations between the various clinical parameters, the significant initial and post-treatment CT scan parameters, with the outcomes of the patients, were determined.

Pearson chi-square test or Fischer's exact test were used to find associations between parameters and outcome. The chi-square test was used when the proportion of cells with an expected frequency of less than five was less than or equal to 20% of the cells. Fischer's exact test was used otherwise. The level of significance was set at 0.05, two-tailed.

RESULTS

For a period of two years, from February 2000 until April 2002, twenty-four cases were included into the study. Out of the 24 patients, 15 (62.5%) were male and 9 (37.5%) were female. Almost all patients were Malay, except one who was a Chinese. Sixteen patients (66.6%) were less than 6 months old. The mean age was ± 5.6 months. Out of these, 8 (33.3%) were under 3 months, and another 8 (33.3%) were between 4 and 6 months. Four patients (16.7%) were between 7 and 9 months, and 4 (16.7%) were between 10 and 12 months. No patient was older than 1 year. All patients were diagnosed with meningitis.

Most of the patients had a long period of illness before being diagnosed with subdural empyema. Only 7 patients (29.2%) were diagnosed with subdural empyema after less than 5 days of illness. Seven patients (29.2%) and 8 (33%) were diagnosed at between 5-10 and 10-15 days of illness, respectively. Only two patients (8.3%) were diagnosed after more than 15 days' illness.

All patients but one had seizures at presentation. Of those, 9 (39.1%) had focal seizures and 14 (58.3%) had generalized seizures. Only six (25.0%) had clinical evidence of hemisyndrome at presentation. For level of consciousness at presentation, most patients were 'drowsy and disorientated' (70.8%). Three patients (12.5%) were 'alert and orientated'. Four patients (16.7%) showed 'response to stimulation only'. There was no patient in the 'no purposeful response, even to pain' group.

Almost all (95.8%, 23 patients) patients had a frontal subdural empyema, except for one. Nineteen (79.2%) had a parietal extension; 6 (25.0%) had a temporal extension; while 3 (12.5%) had a parafalcine extension of the subdural empyema. None had an occipital extension of the subdural empyema. Most (79.2%, 19 patients) had bilateral subdural empyema.

Sixteen patients (66.7%) had a subdural empyema less than 10 mm thick. In 3 patients (12.5%), the thickness was more than 15 mm. Four patients had evidence of midline shift secondary to the subdural empyema, of whom most were less than 5 mm (3 patients). Most of the patients (75.0%, 18 patients) had a volume of subdural empyema of less than 100mls, while 2 patients (8.3%) had a volume of more than 150 mls. Of the 24 patients, 6 (25.0%) had hydrocephalus on the initial CT scan. Three patients (12.5%) had hypodense areas on the initial CT scan; of these, 2 had multiple hypodense areas.

Most of the patients (87.5%) had enhancement of the empyema only. Only one patient had enhancement of the ventricles and empyema. One patient had enhancement of the cerebrum adjacent to the empyema.

Over half of the patients (62.5%) had an interval of less than two days between the CT scan and surgery. Four patients (16.7%) had a slightly longer interval, of 3 to 5 days. Only four patients (16.7%) had a long interval (9-11 days) between CT scan and surgery.

All patients were treated with burrhole and drainage for the subdural empyema. They were also treated intravenously with broad-spectrum antibiotics for at least six weeks. The antibiotics were changed according to the culture and sensitivity of the organism from the blood and CSF.

Of the 6 patients with hydrocephalus by initial CT scan, 3 (50.0%) had an external ventricular drain (EVD). The other three patients (50.0%) were treated by insertion of Rickham's catheter. Only 5 patients (20.9%) had a revision of surgery; of them, 4 had a single revision and one had more than one.

Four patients (16.7%) had positive culture by CSF. Twelve patients (50.0%) had a positive blood culture. One patient had a positive culture from both blood and CSF. Seven patients (29.2%) had no growth from both blood or CSF. Nineteen patients (79.2%) had a causative organism, of whom, 2 had no positive culture blood or CSF. For these 2 patients, the causative organisms were detected by serological study of the CSF. Eleven patients (57.9%) had *Haemophilus influenzae*, four (21.1%) had *Streptococcus* species; *Staphylococcus* species were detected in two patients (10.5%) and *Pseudomonas* species was seen in one patient. One patient had two organisms, *Neisseria meningitidis* and *Escherichia coli*.

In the post-treatment CT brain scan which was performed at least six weeks after the initial

CT scan, several findings were noted. Only 5 (20.8%) of the 24 patients had a residual lesion. Seven (29.2%) had hydrocephalus at post-treatment CT scan, while 7 (29.2%) had cerebral atrophy. A high percentage of patients (50.0%) had hypodense areas, which could represent areas of infarction or gliosis.

Of the 24 patients, 6 (25.0%) still had seizures on follow-up. All of these had generalized seizures. Three out of four patients with hemisyndrome on admission recovered completely (75.0%). The patient who did not recover had severe neurological deficit at outcome. For functional status on follow-up, a high percentage of patients (58.3%) had an excellent outcome, with no residual neurological deficit, five (20.8%) had a mild neurological deficit, three (12.5%) had a severe neurological deficit, and two patients died (8.3%).

Initial CT scan parameters and outcome

For both outcomes 1 and 2, there was a statistically significant predictive value for patients with hypodense areas at the initial CT scan of having a good or poor outcome. However, there was no predictive value for these patients of survival or death (Table 1).

Table 1
Prediction of outcomes using initial CT scan parameters.

CT scan parameters	Outcome 1			Outcome 2		
	Good	Poor	p-value[a]	Alive	Dead	p-value[a]
Parietal lobe						
Yes	14	5	0.533	17	2	0.685
No	5	0		5	0	
Temporal lobe						
Yes	4	2	0.218	5	1	0.423
No	14	3		17	1	
Parafalcine						
Yes	2	1	0.423	2	1	0.101
No	17	4		20	1	
Unilateral/Bilateral						
Unilateral	4	1	0.770	5	0	0.448
Bilateral	15	4		17	2	
Thickness (mm)						
≤ 5	4	1		5	0	
6-10	9	2	0.791	10	1	0.490
11-15	4	1		5	0	
> 15	2	1		2	1	
Midline shift						
Yes	3	1	0.930	4	0	0.360
No	16	4		18	2	
Calculated volume (mls)						
≤ 50	8	3		10	1	
51-100	6	1	0.761	7	0	0.587
101-150	4	0		4	0	
> 150	1	1		1	1	
Hydrocephalus						
Yes	4	2	0.409	5	1	0.591
No	15	3		17	1	
Hypodense areas						
Yes	1	2	0.037	3	0	0.577
No	18	3		19	2	
Enhancement						
None	1	0		1	0	
Empyema only	16	5	0.388	19	2	0.575
Empyema and ventricles	1	0		1	0	
Empyema and cerebrum	1	0		1	0	

[a]Chi-square test/Fisher's exact test

Table 2
Prediction of outcomes using post-treatment CT scan parameters.

CT scan parameters	Outcome 1			Outcome 2		
	Good	Poor	p-value[a]	Alive	Dead	p-value[a]
Any residual lesion						
Yes	4	1	0.680	5	0	0.283
No	15	4		17	2	
Hydrocephalus						
Yes	4	3	0.634	6	1	0.756
No	15	2		16	1	
Cerebral atrophy						
Yes	6	1	0.680	7	0	0.283
No	13	4		15	2	
Hypodense areas						
Yes	8	4	0.132	11	1	1.000
No	11	1		11	1	
Enhancement						
None	15	3		17	1	
Empyema only	3	0	0.277	3	0	0.205
Empyema and ventricles	0	1		1	0	
Empyema and cerebrum	1	1		1	1	

[a]Chi-square test/Fisher's exact test

Post-treatment CT scan parameters and outcome

For both outcomes 1 and 2, there was no predictive value of the post-treatment CT scan parameters in patients with subdural empyema a good or poor outcome, or of survival or death (Table 2).

Clinical parameters and outcome

There was a statistically significant predictive value for level of consciousness at presentation with outcome 2 (survival or dead at outcome). The other parameters showed no statistically significant predictive values to suggest the outcomes for patients with subdural empyema (Table 3).

DISCUSSION

Subdural empyema is a rare suppurative intracranial disease. Even though it is rare in first-world countries, it is relatively common in third-world countries. In the two series reported from South Africa (Bok and Peter, 1993; Nathoo *et al*, 1999), a higher number of cases was seen within a relatively short period. Bok and Peter (1993) reported 90 cases of subdural empyema within a 13-year period. Nathoo *et al* (1999) reported the highest number of cases of subdural empyema (699 cases) ever published in the English literature within a 15-year period. In Turkey, Erdem *et al* (1996) reported 23 cases in a 6-year period. By contrast, in most first-world countries, reported cases were relatively fewer in a similar period. In the USA, Dill *et al* (1995) reported 32 cases within a 22-year period, while Smith and Hendrick (1983) reported 22 cases within a 28-year period. Mauser *et al* (1987), in the Netherlands, reported 102 cases within a 49-year period. In England, Miller *et al* (1987) reported 24 cases in a 14-year period, Cowie and Williams (1983) reported 89 cases in a 28-year period, and Bannister *et al* (1981) reported 66 cases in a 26-year period. In this study, we reported 24 cases of subdural empyema in a 2-year period. This is consistent with previous reports in other third-world countries.

Subdural empyema is more commonly seen in males than females. Of the 24 patients in this study, 62.5% were male and 37.5% female. The male to female ratio was 1.7:1, which was similar to other studies. Nathoo *et al* (1999) reported 62% male and 38% female. Bok and Peter (1993) also reported 68% male and 32% female. However, in other series reported in first-world countries, there have been slight differences in the ra-

Table 3
Prediction of outcomes using selected clinical parameters.

CT scan parameters	Outcome 1			Outcome 2		
	Good	Poor	p-value[a]	Alive	Dead	p-value[a]
Age groups (months)						
< 3	5	3		6	2	
4-6	6	2	0.133	8	0	0.182
7-9	4	0		4	0	
10-12	4	0		4	0	
Blood culture						
Yes	11	2	0.185	13	0	0.104
No	8	3		9	2	
CSF culture						
Yes	3	2	0.080	4	1	0.255
No	16	3		18	1	
Organism growth						
H. influenzae	9	2		11	0	
Staphylococcus	2	0		2	0	
Streptococcus	2	2	0.849	3	1	0.432
Pseudomonas	1	0		1	0	
Mixed	0	1		0	1	
None	5	0		5	0	
Level of consciousness						
Alert and orientated	3	0		3	0	
Drowsy and disorientated	14	3		17	0	
Response to stimulation	2	2	0.086	2	2	0.008
No response even to pain	0	0		0	0	

[a]Chi-square test/Fisher's exact test

tios. Mauser *et al* (1987), in the Netherlands, reported 78% male; Miller *et al* (1987), in London, also reported 78% male. These studies produced a ratio of 3.5:1, which was significantly different from third-world countries (ratio 1.7:1).

The current study concentrated on subdural empyema cases in children; all of the cases were less than one year of age, with a mean age of 5.6 months. Most of the published studies were conducted with all age groups. Nathoo *et al* (1999) reported 14.9% in cases under 5 years of age, while Bok and Peter (1993) reported 14.4% in the same age group. Mauser *et al* (1987) and Bannister *et al* (1981) reported only 10% in cases under 10 year of age. Smith and Hendrick (1983) reported 63.6% in cases under 2 year of age.

Since all of the patients were under 1 year of age, the patients' ages were reclassified into months. Sixteen patients (66.6%) were under 6 months. This is to be expected, since almost all patients had subdural empyema secondary to meningitis. Hussain *et al* (1998), in their cross-sectional study involving 5 centers in Malaysia, reported 90% of postneonatal childhood meningitis case were under 5 years of age, of whom half were under 6 months.

Neglected rhinogenic infection resulting in paranasal sinusitis was the common cause of empyema. Other causes included otogenic causes, meningitis, trauma and post-intracranial surgery (Nathoo *et al*, 1999). In this study, all patients had subdural empyema secondary to meningitis. Nathoo *et al* (1999) also reported a high incidence of subdural empyema secondary to meningitis (70%) in the under-5-years age group. Paranasal sinusitis was the cause in 11% of cases in the same age group. However, Smith and Hendrick (1983) only reported 18% incidence of subdural empyema secondary to meningitis in children. This is because their study also included patients above 12 years (7 patients aged 13 to 16 years). Nothing was mentioned regarding the ages of the patients in the postmeningitic group.

Subdural empyema is one of the known complications of childhood meningitis, it is quite rare. Subdural empyema usually develops when there is secondary infection of the sterile subdural effusion. Other complications include vascular thrombosis and infarction, hydrocephalus and brain abscess. Syrogiannopoulos *et al* (1986) reported an incidence of 6.8% subdural effusion in 2,013 bacterial meningitis cases, of whom only 1.7% of cases were confirmed as subdural empyema. However, Snedeker *et al* (1990) reported a higher incidence of subdural effusion in their series (39%), but could not confirm the incidence of subdural empyema since 7 patients had subdural paracentesis, of whom only one had subdural empyema (cell count >20,000/mm^3). Hussain *et al* (1998) reported an 18.3% incidence of subdural effusion secondary to meningitis in Malaysia.

The periods of illness, before the patients were diagnosed with subdural empyema, were long. Most of the patients (71%) were ill for more than 5 days before diagnosis. As most of the patients had subdural empyema secondary to meningitis, there will usually be a lag before developing the subdural empyema. The development of new or persistent neurological deficits, prolonged pyrexia, coma, persistent seizures and increasing head circumference during treatment will preclude suspicion of the development of subdural effusions in these patients (Suchet *et al*, 1988; Snedeker *et al*, 1990). Syrogiannopoulos *et al* (1986) reported a delay of 6.6 days before a diagnosis of subdural empyema was made. In patients with a benign subdural effusion, there was a longer delay, of 10.5 days. This difference was statistically significant ($p<0.05$).

Prolonged fever, focal and generalized seizures, focal neurological deficits, and altered levels of consciousness were the common modes of presentation in our series. All patients had seizures at presentation, except one. Fifty-eight percent (14 patients) developed generalized, and 39% (9 patients) focal, seizures. Only 25% of patients had a focal neurological deficit at presentation. This contrasts with other studies reporting a lower incidence of seizures. Nathoo *et al* (1999) observed that fever (77%), neck stiffness (74%), headache (32%) and focal seizures (29%) were the common initial presenting features. Bok and Peter (1993) observed that headache (71%), neck stiffness (60%), fever (58%) and altered level of consciousness (56%) were the common initial presenting features. Seizures were only seen in 34% of patients. Erdem *et al* (1996) observed that headache (100%), neurological deficit (83%), fever (78%), and vomiting (48%) were the common initial presenting features. Epilepsy was only seen in 30% of patients. Smith and Hendrick (1983) in their subdural empyema in children series only reported clinical features of subdural empyema in the 12 to 16 years age group. Nothing was mentioned about the clinical features of the under-12-years age group. The reason for the high incidence of seizures in our series was because the subdural empyema was mainly secondary to meningitis. Pusponegoro *et al* (1998) observed that 100% of their bacterial meningitis patients had fever and seizures at presentation, and 54% had neck stiffness.

The CT scan is a very important diagnostic tool for subdural empyema (Zimmerman *et al*, 1984). Other radiological diagnostic methods include ultrasound of the cranium, MRI, angiography and radionuclide imaging (Chen *et al*, 1988; Sze and Zimmerman, 1988; Kim and Weinberg, 1976). However, currently, the CT scan, MRI and ultrasound remain the important diagnostic tools. Angiography and radionuclide imaging are mainly historical methods. Some authors had used non-radiological diagnostic methods, such as transillumination and subdural paracentesis (Syrogiannopoulos *et al*, 1986; Snedeker *et al*, 1990). These are important, especially in cases of subdural empyema secondary to meningitis.

Even though there were few reports of CT scan failure to detect early subdural empyema, it remained an important radiological diagnostic tool (Dunker and Khankoo, 1981; Baum and Dillon, 1992). MRI was noted to be more sensitive than CT scan in detecting early lesions, parenchymal abnormalities, and to differentiate between epidural and subdural empyema and between parenchymal abscess and subdural empyema (Weingarten *et al*, 1989). However, due to the unavailability of MRI scannes in all centers, it cannot be widely used as a diagnostic tool. In the east coast of Malaysia during the study period, MRI scanning was only available in the

Hospital of the Universiti Sains Malaysia.

Almost all of our patients had subdural empyema secondary to meningitis. The CT scan of the brain also showed other complications of meningitis, such as infarction (12.5%), hydrocephalus (25%), ventriculitis (4%), and brain abscess (4%). Hussain *et al* (1998) reported an 11.3% incidence of hydrocephalus among the 71 confirmed cases of bacterial meningitis in their series.

In this study, we observed that the presence of hypodense areas, which could be attributed to areas of cerebral infarction in the initial CT scan of the brain, had a significant influence ($p<0.05$) on the outcome of the patient. Patients with hypodense areas were observed to have poor outcomes compared with patients without hypodense areas. However, the presence of hypodense areas had no significant influence on the survival of patients. The other parameters, *ie* extension of subdural empyema, thickness, estimated volume, midline shift, hydrocephalus, and patterns of enhancement, had no bearing ($p>0.05$) on patient outcomes. Nathoo *et al* (1999) also observed that patients with cerebral infarction (41.2% died) and ventriculitis (80.0% died) had significantly lower rates of survival. In this study, only one patient with an associated ventriculitis had a 'minimal neurological handicap' as the outcome (good outcome).

We correlated the initial CT scan parameters with the level of consciousness at presentation. Of all the parameters, only parafalcine extension of the subdural empyema had a significant correlation with level of consciousness ($p<0.05$). The other parameters did not show any correlation with level of consciousness at presentation. Only 3 patients had a parafalcine extension, and of those, 2 patients showed 'response to stimulation only' and 1 was 'drowsy and disorientated' at presentation. All three had bilateral frontal and parietal extension of the subdural empyema, with an estimated volume of more than 100 mls. These features correspond to an extensive or diffuse extension of the subdural empyema. We can conclude indirectly that patients with a diffuse subdural pus collection will usually have a lower level of consciousness than patients with localized subdural pus collection. Mauser *et al* (1987) observed that patients with a diffuse subdural pus collection had a lower rate of survival without severe disability than patients with a localized accumulation. They observed that the extent of the subdural pus accumulation was dependent on the level of consciousness at presentation.

All patients were treated with both medical and neurosurgical management. Broad-spectrum antibiotics were started at the initial diagnosis of meningitis and changed accordingly based on culture and sensitivity results. For neurosurgical management, all patients had burr hole evacuation with catheter drainage. In our study, the mortality of 8.3% (2 patients) is comparable to the previous studies done in the computed tomography era. In the computed tomography era, the burr hole had the advantage over craniotomy. Erdem *et al* (1996) reported 23 cases treated with burr holes, with a mortality of 8.7% (2 deaths). Bok and Peter (1993) reported 75 patients treated with burr holes, with a mortality of 6.7%.

However, in the pre-computed tomography era, craniotomy was noted to be superior to burr hole, with lower mortality. Bannister *et al* (1981) reported 29 cases treated solely by burr holes, with a mortality of 48%. Twenty-four cases in the same series were treated by primary craniotomy, with lower mortality (8%). With the availability of computed tomography, neurosurgeons can plan surgery and locate precisely the site of the subdural empyema. This makes burr hole evacuation a better choice for subdural empyema treatment. It is far safer to advocate a multiple burr hole procedure than a large craniotomy, where possible catastrophic brain swelling, infarction, or hemorrhage may result from an injudicious aggressive opening of the dura (Bok and Peter, 1993).

A few authors compared craniotomy and burr hole evacuation as two options in managing subdural empyema. Miller *et al* (1987) observed that there was no significant difference in the mortalities between these two methods of surgery (17.6% in the burr hole group and 16.7% in the craniotomy group). Mauser *et al* (1987) observed that the type of first neurosurgical procedure had no significant bearing on patient outcomes.

The bacteriological spectrum of subdural empyema varies according to its primary cause. Most of the published studies showed a variety of causes, with paranasal sinusitis and otitis media the common primary causes. Nathoo *et al* (1999) observed that *Streptococcus* species was the most common causative organism (25%). However, a sterile culture was also commonly seen (18%). Bok and Peter (1983) also observed a high *Streptococcus* species in their series (36%). They also had a high sterile culture (30%). Bannister *et al* (1981) had a high incidence of *Streptococcus* species (36%) and anaerobic organisms (27%) in their series. In this study, we had a 79.2% (19 patients) positive detection of organisms either from blood culture, CSF culture, or serological tests, of whom 58% (11 patients) grew *Haemophilus influenzae*. *Streptococcus* species were only seen in 21% (4 patients) of patients. This is because the subdural empyema cases were mostly secondary to meningitis. Hussain *et al* (1998) observed 48% cases of *Haemophilus influenzae* type b out of 71 cases of bacterial meningitis. Kline and Kaplan (1988) observed 64% cases of *Haemophilus influenzae* type b among 25 bacterial meningitis patients. In a study of subdural effusion in bacterial meningitis by Syrogiannopoulos *et al* (1986), *Haemophilus influenzae* was the most frequent etiologic agent (74%), while *Streptococcus pneumoniae* was the next most common causative agent (13%). Snedeker *et al* (1990) studied the neurological sequelae of bacterial meningitis patients who developed subdural effusion and compared with the ones who did not develop it. They only studied *Haemophilus influenzae*, *Streptococcus pneumoniae* and *Neisseria meningitidis*. Out of the three organisms, *Haemophilus influenzae* was the most common (74%). *Streptococcus pneumoniae* was the next common (18%). *Haemophilus influenzae* is also the leading cause of bacterial meningitis in developing countries, causing high morbidity and mortality (Salisbury, 1998).

Post-surgery, and after completion of six weeks' antibiotic treatment, the patients underwent another CT scan examination. One patient had both CT scan and MRI within a short period of time. However, since that patient had an excellent outcome, no additional information was given by the MRI. Post-treatment CT scan of the brain is very important for detecting any residual lesion or complications of subdural empyema. Only 21% of patients had a residual effusion at 6 weeks' follow-up. Snedeker *et al* (1990) observed 44 patients with subdural effusion secondary to bacterial meningitis, and observed that several of the patients still had a residual effusion at 1-month follow-up. At 3 months follow-up, only one patient had a residual effusion.

Two patients had enhancement of the ventricles and cerebrum in the post-treatment CT scan. Both of them had a poor outcome. However, this was not statistically significant ($p>0.05$). The other parameters, *ie* presence of residual empyema, hydrocephalus, cerebral atrophy, and hypodense areas, also show no significant statistical significance. We conclude that post-treatment CT scan of the brain parameters do not predict the outcomes of patients with subdural empyema.

In our study, we observed a mortality of only 8.3% (2 patients). This is consistent with other studies done in the computed tomography era. Nearly all patients with focal neurological deficits had fully recovered. One patient who did not recover had a poor outcome.

In the initial CT scan, the presence of hypodense areas had a significant influence on patient outcome ($p<0.05$). The other parameters, *ie* extension of subdural empyema, thickness, estimated volume, midline shift, hydrocephalus, and patterns of enhancement, had no bearing on patient outcome ($p>0.05$). In the post-treatment CT scan of the brain, no parameters had significant bearing on patient outcome ($p>0.05$).

In predicting the outcome of patients using several clinical parameters, we observed that the level of consciousness at presentation had a highly significant bearing on patient outcome ($p<0.01$). Two patients who showed 'response to stimulation only' died. Other patients who were 'alert and orientated' and 'drowsy and disorientated' were alive at outcome. Other parameters, *ie* age, blood culture, CSF culture, and causative organism, had no bearing on patient outcome ($p>0.05$). These observations were consistent with the previous observations by Mauser *et al* (1987) and Bannister *et al* (1981).

Mauser *et al* (1987) observed that patients who were comatose at presentation, elderly or younger than 10 years, delay starting antibiotics, had a sterile culture, and otogenic etiology, had a poor outcome. Bannister *et al* (1981) also observed that patients who were comatose at presentation, had diffuse extension of subdural empyema, cerebral herniation, and sterile culture, had a poor outcome. From these observations and our study results, the level of consciousness at presentation had a significant bearing on patient outcome.

Mauser *et al* (1987) and Bannister *et al* (1981) observed that patients with sterile culture had a poor outcome. However, in our study, five patients had no causative organisms detected, and all five had a good outcome. This contradicts the observations of Mauser *et al* (1987) and Bannister *et al* (1981). A sterile culture does not signify that the empyema is sterile. It is most likely that the causative organisms might be fastidious and proper collection and culture methods were needed. Most of our patients had also sought treatment elsewhere before coming to hospital. Most of the time, they had taken a course of antibiotics that partially treated the disease. As mentioned by Hussain *et al* (1998), most Malaysian bacterial meningitis cases had no lumbar puncture due to a widespread belief that lumbar puncture will lead to later paralysis or impotence. In the 5 centers, the lumbar puncture rate was only 16.3%. Without lumbar puncture, the yield of organisms is usually low.

Conclusion

This study was conducted to predict the outcomes of patients with intracranial subdural empyema using initial, and post-treatment, brain CT scan parameters. The other objectives included correlating the clinical features with the initial CT scan parameters and the outcomes. It was intended to use the clinical features and the initial CT scan parameters to prognosticate the patient outcomes before surgery in Southeast Asian countries.

Twenty-four clinical and CT scan variables were studied, with two sets of outcomes. The first set measured good and poor outcomes. The second set measured patient survival.

The only significant CT scan variable to predict patient outcome was the presence of hypodense areas in the initial CT scan, which could be attributed to areas of cerebral infarction, which had a significant influence ($p<0.05$) on outcome. Patients with hypodense areas had poor outcomes compared with patients without hypodense areas. None of the post-treatment CT scan parameters had a significant bearing on patient outcomes.

The level of consciousness at presentation had a significant influence ($p<0.01$) on patient outcomes. Patients with low levels of consciousness tended to have poor outcomes. Correlating the level of consciousness with the initial CT scan parameters, only the presence of parafalcine extension had a significant correlation with the level of consciousness.

We observed that patients with an extensive subdural empyema had a good outcome if treated early and aggressively with antibiotics and burr hole evacuation. These must be performed before the patient has deteriorated in level of consciousness.

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