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THE USE OF CT SCANNING IN DEMENTIA

A Systematic Review

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Abstract

While reversible cases of dementia are rare once detected, the patient may benefit from treatment. This paper examines the cost-effectiveness of computerized tomography (CT) scanning as a screening test for potentially reversible dementia. A systematic review was carried out to identify the proportion of patients with dementia above and below the age of 65 years with a theoretically treatable condition and the proportion of these patients who would benefit from neurosurgery. Information was combined with epidemiological and financial data relating to Scotland to model the costs and benefits of implementing a national screening program. Subdural hematoma, normal pressure hydrocephalus, and brain tumours are rare conditions treatable by neurosurgery. A scanning and treatment program for Scotland would cost £4.6 million per annum. Of 531 reversible cases detected, 136 would benefit from neurosurgery, 369 would not benefit, and 26 would die as a result of surgery. Treating normal pressure hydrocephalus reduces overall quality-adjusted survival. The most cost effective screening strategy is to scan all patients but treat only subdural hematomas, gaining 178 quality-adjusted life-years (QALYs) at a cost of £14,171 per QALY for patients aged 65 at the time of the scan. The corresponding figures for patients above and below 65 years are £9,000 and £23,000, respectively. CT scanning appears cost-effective in dementia patients under 65 years. It should be undertaken selectively in more elderly patients. Surgical treatment of normal pressure hydrocephalus may reduce quality adjusted survival and should only be undertaken within clinical trials.

Keywords: CT, Computed Tomography, Senile Dementia, Cost-Effectiveness, Systematic Review

Dementing illness is a major public health problem of growing importance in an ageing population. The cumulative lifetime risk to each individual alive today of becoming severely demented may be as high as 20% (43). Characterized by a distressing and progressive loss of memory and cognitive function, the impact of

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this syndrome on the patient, the patient's family, and the wider society is substantial. Persons with dementia can require almost total care.

Although prevalence is known, lack of data on survival from onset (and difficulty in dating onset) makes it difficult to calculate the incidence of dementia. There are over 50 different causes of dementia (29). Almost all cases of dementia in people over 65 are due to Alzheimer's disease (50–70%) or multiple cerebral infarctions (20%), and are irreversible and progressive.

Alzheimer's disease is a progressive and irreversible condition leading to premature death (29). Age is the biggest risk factor, followed by family history. There is no specific diagnostic test, and reported prevalence varies according to the test used (30). There is no cure, although a number of symptomatic treatments are currently undergoing trials. Explanation and prognosis is important for the family. Management is by supportive care.

Although definitive diagnosis of Alzheimer's disease is by postmortem histopathology of brain, there is no universally accepted pathological criterion (29). Standardized clinical criteria such as the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association Work Group (NINCDS-ADRDA) Criteria and the *Diagnostic and Statistical Manual of Mental Disorders,* Third Edition, Revised (DSM-III-R) give approximately 70%–90% accuracy (10;23;29;31;61).

In research settings, Computed Tomograph (CT) has been used to increase the specificity of clinical scales for diagnosing Alzheimer's disease (29). However, the clinical purpose of scanning in dementia is not to confirm the diagnosis, but to look for potentially treatable causes. The CT scan makes it possible to diagnose structural lesions such as tumors, subdural hematomas, hydrocephalus, and strokes at virtually no risk to the patient (31).

An expensive diagnostic test should only be used if it provides useful information in terms of diagnosis, prognosis, or both. To not perform imaging of a clinically established diagnosis is often considered poor professional practice. However, reducing requests for CT scanning would free important resources for much higher priority services (21). CT scanners are in heavy demand for other clinical investigations. Therefore, we must consider the marginal cost of using them in dementia if scanning confers no advantage upon the demented patient. Indeed, one center has reported that psychogeriatric assessments are severely restricted (to one per week) by a lack of access to CT scanning (23).

Functional imaging techniques such as single photon emission computed tomography (SPECT) and positron emission tomography (PET) measure changes in cerebral blood flow, metabolism, and neurotransmitter activity. While having potential to study a range of neurological processes and disease states, to date most research has explored whether the techniques can be used as definitive tests for Alzheimer's disease. These studies report a range of values for sensitivity and specificity. Such variation reflects differences between studies in the selection of sample population and methods employed to analyze images (3;8;9;18;29;39;40;45;46;47;57). The diagnostic value of SPECT and PET is therefore yet to be proven.

The advantage of magnetic resonance imaging (MRI) over CT in the detection of reversible dementia remains controversial (1;14;29;58). In Scotland the lack of availability of MRI scanners precludes the routine use of this technology.

METHODS

The aim of this review was to define what proportion of dementias are due to a theoretically treatable cause, what proportion would actually be treated if diagnosed by CT scanning, and what proportion of those treated would actually benefit. A systematic literature review was conducted using the search terms CAT, CT, tomography, and dementia. The MEDLINE and Embase databases were searched up to December 1997, and references from personal contacts were accessed. Reference lists of all useful papers obtained were also used. Observational studies were included since few clinical trials were available.

The data from the literature review were used to model the annual costs and benefits to the National Health Service (NHS) in Scotland of using CT to examine all newly diagnosed cases of dementia and treating all the potentially reversible disease discovered. Given that the literature tends to report findings from studies in patients above or below 65 years, the model used produced cost-effectiveness figures relevant to these age groups.

Table 1 assembles the relevant data necessary for the construction of the model. These data are largely based on Clarfield's meta-analysis of 2,889 patients (12) and some 1,913 additional patients from other studies by Bradshaw et al. (7), Jellinger (28), Dietch (16), and Martin et al. (38), not identified by Clarfield. These data are therefore based on studies of over 4,800 patients.

LITERATURE REVIEW

Prevalence of Reversible Dementias

The majority of the literature cited is from the 1980s and early 1990s. The literature search (detailed above) found little of relevance from the late 1990s.

Dementia cases can be considered in two distinct groups. Dementia occurring in young people (under 55) should be investigated, since 20.7% of such patients have potentially reversible disease (12;59). Dementia becomes a very common condition over the age of 65, occurring in 5–15% of the population. In this age group, only 5.4% of cases are potentially reversible, and dementia is a more frequent cause of death than heart attack or stroke (22;43;52;53). Prognosis is poor and almost all cases are progressive and fatal. Those who are affected survive only a third as long as healthy people of the same age and sex (2;7;11;20;49;64).

Reversible dementia is much less common than previously suspected (7;32). The literature on reversible dementia has shifted over the past 20 years, changing in emphasis from looking for reversible causes for dementia to identifying treatable components in irreversibly demented patients. In 1972, Marsden and Harrison (37) reported that 15% of a series of 106 patients with presumed presenile dementia had conditions amenable to treatment. Unfortunately, there was no follow-up to determine whether patients actually did improve. Their patients were mostly young, and all had been referred to a specialist center for expensive and specialist radiology, suggesting that their doctors suspected a reversible etiology (32). In fact, only 5% of patients who actually had dementia in Marsden and Harrison's series had potentially treatable lesions (37). Smith and Kiloh (59) examined 200 consecutive patients at a neuropsychiatric institute and found only 3.8% of demented patients over age 64 had potentially treatable lesions.

Early studies of CT scanning in dementia were concentrated in secondary centers to which patients were referred specifically for investigation by CT scanning,

Table 1. Values Used for Baseline Model

Variable	Best	Baseline	Worst	Source
Incidence of dementia (aged 75–85)		3.5 per 100 person-years		(65)
Prevalence of dementia	5% (15)	9.3% (22)	15% (43)	(15;22;30;43;52;53)
Cost of CT scan	£128.57	£167.96	£292.30	pers. com. + SHPIC costing unit + transport (est)*
Proportion of dementia reversible	25.5% (37)	13.7% (12)	4.6% (12)	(12;37;38;42)
Proportion of reversible dementias detectable by CT	35% est	27.5% (12)	10% est	(12)
Proportion of all dementia with lesions detectable by CT	10.4% (7)	6.6% (28)	3.8% (12)	(7;12,28;38)
Proportion of CT detectable reversibles due to tumor	63.5%	53.36 (weighted avg.)	46.3%	(7;12;28;38)
Proportion of CT detectable reversibles due to SDH	25% (38)	11.13 (weighted avg.)	7.7%	(7;12;28;38)
Proportion of CT detectable reversibles due to NPH	11.5% (7)	35.51 (weighted avg.)	46% (12)	(7;12;28;38)
Probability of mortality with surgery for tumor	0.02	0.05	0.1	est
Probability of tumor improvement	0.5	0.18	0.1	(50)
Probability of mortality with surgery for SDH	0.02	0.05	0.1	(58)
Probability of improvement with surgery for SDH	0.9	0.8	0.7	(58)
Probability of mortality with surgery for NPH	0.02	0.05	0.1	(58;63)
Probability of improvement with surgery for NPH	0.4	0.2	0.1	(63)
Tumor mortality, no surgery (months)	12	6	3	(6;7;58)
Tumor mortality with surgery (months)	36	12	5.5	(6;7;58)
Tumor operation cost		£6,088		Dundee Teaching Hospitals 1996–97

(*Continued*)

Table 1. (*Continued*)

Variable	Best	Baseline	Worst	Source
Life-years gained by tumor treatment (months)	24	6	2.5	(6;7;58)
SDH operation cost		£2,501		Dundee Teaching Hospitals 1996–97
Life-years after improvement from SDH operation	100%	100% (of 16 ys)	50%	(58)
Life-years gained if untreated SDH	7%	25%	75%	(58)
Life-years gained after failure to improve from SDH operation	7%	25%	75%	(58)
NPH operation cost		£2545		Dundee Teaching Hospitals 1996–97
Life-years after improvement from NPH operation	100%	75%	75%	(58)
Life-years gained if untreated NPH	75%	75%	75%	(58)
Life-years gained after failure to improve from NPH operation	75%	75%	75%	(58)
Average survival at age 65, male		13.4 ys		(26)
Average survival at age 65, female		16.9 ys		(26)
Average survival at age 65		16 ys		(11)
Average survival with dementia, age 65	37.5% (6 ys)	33% (5.3 ys)	24% (3.8 ys)	(11;41;64)

Abbreviations: SDH = subdural hematoma; NPH = normal pressure hydrocephalus.
* Estimation based on limited data.

a new and exciting technique, whereas most dementia cases are ambulatory, community-based outpatients (33). This difference resulted in a significant bias toward organic conditions with focal neurological signs in the study samples and an overestimation of the proportion of reversible dementia in the population. Later community-based studies have found significantly lower rates of potentially reversible dementia (12). Another problem is that most studies report only potentially reversible dementia because long term follow-up is either limited or absent (33).

The Clarfield meta-analysis involving almost 3,000 demented patients found that although 13.7% of all dementias were potentially reversible, in practice only 3.1% fully reversed and 8.3% partly reversed (12). As most studies were hospital-based, Clarfield analyzed the community-based studies separately and found a less than 1% cure rate (12). Only 11 of the studies provided follow-up of their patients, and in those only 3% fully resolved. Rubenstein (55) reports a small meta-analysis of published studies (406 patients), by Wells (66) and Smith and Kiloh (59), which supports a much lower prevalence of truly reversible dementia. Two-thirds of the 9% of patients with mass lesions or normal pressure hydrocephalus did show some improvement with appropriate therapy, but follow-up was limited and the study was hospital-based.

The results of more recent research on demented elderly outpatients show only a very small percentage (as low as 1%) have completely curable conditions (33). Roberts and Caird (51) investigated 288 confused elderly patients and conducted a literature review of studies involving over 1,300 subjects. They concluded that "CAT scanning should be reserved for those patients with the recent onset of confusion and focal signs of insidious onset and those with seizure disorders" (51). Bradshaw et al. (7) reported 500 cases referred for CT scanning to a specialist neuroradiology unit, where 5% of the 325 patients with dementia and no other signs or symptoms were found to have a potentially treatable structural lesion. Age was not helpful in predicting diagnosis, perhaps because of selection bias in referral to such a unit.

Clinical prediction rules are a potent tool for increasing efficiency of diagnostic procedures and reducing health service costs. Martin et al. (38) evaluated four such clinical prediction rules (7;16;34) and demonstrated that many lesions would have been missed had CT scanning been done under these criteria. The authors concluded that "An optimal prediction rule for guiding the application of CAT scanning for dementia remains to be developed." Dietch (16) lists 11 criteria to characterize patients unlikely to benefit from CT scanning: dementia for at least 1 month; no head trauma in week preceding dementia; gradual onset; no history of malignant tumor, cerebrovascular accident, seizures, or urinary incontinence; no focal cerebral signs, papilloedema, visual field defects, apraxia, or ataxia of gait. Although his sample of patients numbers only 100, the incidence of treatable lesions was 1%, compared with 11% treatable lesions in another 100 patients who rejected at least one of his criteria. Bradshaw et al. (7) found "Only a speech disorder, headache, focal signs and papilloedema produced a better pick up rate than scanning all 500 patients indiscriminately". Larson et al. (33) conducted prospective studies on outpatients and found shorter duration of symptoms and less severe dementia characterize patients with so-called reversible dementia.

Only three rare but potentially reversible conditions are identified by CT screening: subdural hematoma, brain tumor, and normal pressure hydrocephalus (27;31).

Normal Pressure Hydrocephalus

Normal pressure hydrocephalus (NPH) occurs in less than 2% of dementia cases (12;13) and generally affects a younger age group of patients: half of all cases are in patients under age 60. Shunting has been reported to improve or even cure the condition, but good evidence for this finding is lacking and postoperative complication rates are high, with infection, postoperative subdural hematoma, shunt occlusion, strokes, and sometimes death occurring in up to one-third of all patients (13;14;60;62). There is a large radiological overlap with Alzheimer's disease, and it is often reported that only those patents with classic clinical signs of NPH do well (5;13;17;24;44;56;62).

Rubenstein has commented that "In most reported series, more than half of [NPH] patients respond favorably to surgical therapy" (55). On the other hand, Clarfield (13) cites a follow-up of 12 patients (nine did not have a shunt inserted; three had a shunt inserted "many months after the diagnosis"), reporting that "the clinical course of these patients varied in a manner similar to [another 37 patients] who had a shunt inserted [shortly after diagnosis]". Furthermore, "Fully three fourths of those with NPH who were not operated on in this series showed no serious cognitive decline after a reasonable period of follow-up." Vanneste et al. (63) reviewed 127 patients with idiopathic NPH and found improvement after shunting in only 15%. Patients may do equally well without shunting at all. On balance it appears that patients may experience more harm than good by being subjected to these invasive surgical procedures, which have high associated morbidity and mortality (5;13;24;44). Although more than half (55%) of young patients respond favourably to surgery (44), most CT-detected NPH patients would be frail, elderly, and without the classic clinical triad of gait disturbance, memory loss, and incontinence said to indicate good prognosis for surgery, especially in this elderly group (5). Clarfield (13) suggested that only this clinical triad should be used to detect patients with NPH, since CT scan findings will not influence subsequent treatment.

In a study among demented patients undergoing shunting, 60% were improved; however, 45% of patients overall had significant postoperative complications directly related to the procedure, including 41% of those who did not improve (62). In addition, 9% of patients died, 9% developed seizures, and 18% had significant postoperative infections. The best prognosis was found in those who showed a clinical improvement after surgery and had a duration of illness of less than 6 months (62). In a different study subdural hematomas complicated shunting in 5 of 24 patients (24). In another, only 31.6% improved while 4 of 62 patients developed seizures, 7 of 62 required revision, 6 of 72 shunts required removal or ligation, and 2 of 74 patients died as a direct result (5).

Operative deaths are primarily effects of anesthesia in this elderly and sometimes fragile population (5). Nevertheless, several studies claim substantial benefit in younger patients receiving a shunt (5;13;24;44;62).

Tumors

Brain tumors are a rare cause of dementia, occurring in 1 to 4% of cases. The incidence of cerebral tumours may be no greater in the demented population than in the general population. Most brain tumours are malignant, with 25% proving to have spread from another (advanced) cancer, the most common being bronchus and breast (14). Survival rates, even with treatment, are extremely poor, and so perhaps these conditions should not be regarded as reversible (6;7). Less than 15%

are the potentially curable meningiomas; surgical treatment does not always reverse the dementia and complications are frequent (7;50). Since the majority of primary tumours occur in those under 65 (who would be classified as presenile dementia) and the duration of symptoms tends to be quite short before diagnosis is made, it is unlikely that CT scanning of patients with senile dementia will find many curable tumors. Even where benign meningiomas are diagnosed, the prognosis can be very poor (50).

Subdural Hematomas

Chronic subdural hematomas (SDH) in the elderly can respond very well to surgery, especially if the dementia has been of short duration (4;7;48). SDH, however, is the rarest of the potentially reversible conditions that might be found by CT scanning, occurring in only 0.4% of demented patients (12). Patients usually have a suggestive history of head injury (66%), tend to be under 70 (91.2%), have significant focal neurological signs and symptoms, and a duration of symptoms of less than 6 months (36). CT scanning will not detect all cases of SDH, especially those of longer duration (65). Although false negatives occur in about 10% of cases, false positives are fortunately very rare (19;65).

The Model

Costs of CT Scanning. It is difficult to determine an accurate cost for a CT scan. It is important to include not just the cost of the scan, but also additional costs such as transport, possibly requiring a nurse escort, and fixed costs such as hospital overhead. In addition, to screen all newly diagnosed demented patients in Scotland would require an extra 14,000 CT scans per year, which are unlikely to be within existing resources. The marginal costs therefore are greater than the single cost of a CT scan in an existing center. A range of cost estimates were examined. A single noncontrast CT scan at the Royal Infirmary of Edinburgh NHS Trust is estimated to cost £103.57, excluding additional costs (such as transport) (J. Best, personal communication). The SHPIC costing unit calculated the cost of a noncontrasted CT scan at £142.96 for Dundee Teaching Hospitals NHS Trust (as detailed on their Finance Department costing spreadsheet, this cost includes room charge, administration, overheads, radiographer, radiologist, nurse, laser film, and processing, but not transport or community costs). These estimates do not include capital charges since the applicable scanners currently in use are fully depreciated. If new CT scanners had to be purchased to accommodate the extra demand at a cost of £450,000 each and depreciated over a 10-year life, the cost for each noncontrasted CT scan would be £267.30. These figures still exclude the resulting transport and community costs, which cannot be avoided since many of the patients will be diagnosed in the community. An average figure of £25 per patient has been added to cover community costs such as transportation to the nearest CT scanner. This takes the cost of a CT scan on a fully depreciated machine to £167.96 and on a new machine to £292.30. Spiral scanners, which can reduce total scanning time to around 10 minutes, have recently been developed but are not yet in common use in Scotland. The SHPIC costing unit estimates the cost of a single noncontrast spiral scan at the Edinburgh Royal Infirmary to be £64.02, but overhead such as travel costs is unaffected. In addition, the unit cost of each scan is reduced only where the total number of scans carried out in the unit is greatly increased by the reduced scanning time. The opportunity costs of using CT scanners that could be used for other purposes have not been evaluated.

Table 2. Correction for Quality of Life

Quality adjustments	Low	Baseline	High
Tumor/demented	0.2	0.3	0.4
Tumor/surgery/improved	0.6 (58)	0.7 (58)	0.8 (58)
Tumor/surgery/demented	0.1	0.2	0.3
SDH/demented	0.2	0.3	0.4
SDH/surgery/improved	0.7	0.8 (58)	0.9
SDH/surgery/demented	0.1	0.2	0.3
NPH/demented	0.2	0.3	0.4
NPH/surgery/improved	0.7	0.8 (58)	0.9
NPH/surgery/demented	0.1	0.2	0.3

Abbreviations: SDH = subdural hematoma; NPH = normal pressure hydrocephalus.

The costs of surgery for reversible dementia taken from Dundee Teaching Hospitals extracontractual referrals tariff are: brain tumour, £6,088; SDH, £2,501; and NPH, £2,545.

Quality of Life. In assessing the outcome of the various approaches to the treatment of dementia in the elderly, quality, not just quantity, of life must be considered. One way to consider this factor is to measure the benefits in terms of quality-adjusted life-years (QALYs) (35). The calculation of QALYs uses correction factors to adjust for quality of life. The most commonly used values are those based upon the Rosser scale, a 29-cell matrix that assigns values to certain categories of disability and distress (54). However, this is very difficult to apply in the case of dementia where, although patients are profoundly handicapped, they lack the insight to feel severe distress; indeed, in some cases their disability may be more distressing to caregivers and relatives than to the individual. For this study we have adopted the quality-of-life values used by Simon and Lubin (58), which were based upon their assessment of quality of life for demented subjects (Table 2).

RESULTS

Table 1 uses data from the systematic literature review to predict the best and worst possible values for each variable as well as a baseline figure used for the model. The model takes the shape of a tree diagram (Figure 1). Starting at the top of the tree with the number of new cases of dementia in Scotland (14,107), we estimate that 13.7% of all dementias are reversible. The model quantifies the reversible causes detectable by CT scanning and proportions them into likely cause: brain tumor, SDH, and NPH. The outcomes of surgery on these reversible causes are listed under die, not improved (which includes in some cases those made worse), and improved.

In the model 284[1] (53%) patients have tumors, of whom 51 would receive some benefit from an operation; however, 14 patients would die as a direct result of the operation or postoperative complications. The remaining 218 patients would receive no direct benefit from the operation in terms of survival but would have had to suffer an unhelpful operation and might have lower quality of life as a result of operative complications. Fifty-nine patients would be found to have SDH that could be removed surgically; most of this group (80%) could be expected to improve, three patients (5%) would die as a direct result of the operation, and nine (15%) would have had an operation but with no benefit and the possibility of complications.

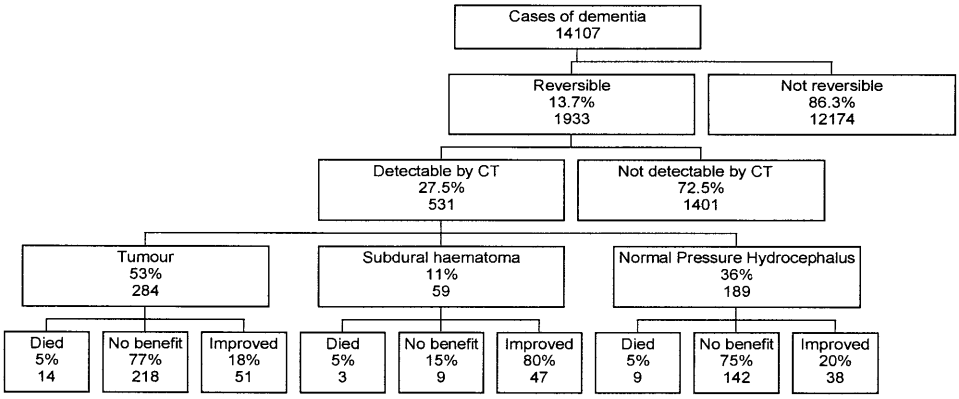

Figure 1. Baseline model of outcomes from CT scanning of all patients developing dementia in Scotland in one year.

It has been optimistically assumed that 38 (20%) of NPH patients could be improved and that postoperative mortality would be 5% (nine patients). One hundred forty-two (75%) patients would gain no benefit from the operation but would still experience the complications described above. The treatment of any postoperative complications has not been evaluated.

In Table 3, life-years gained and lost due to improvement or death from surgery are adjusted for quality of life using the baseline figures from Table 2. With a dementia prevalence of 9.3%, if only SDH patients were treated the total cost to the NHS in Scotland would be £2,517,329 (cost of screening all patients plus SDH operation costs). There would be 178 QALYs gained at £14,171 per QALY. Of course, this strategy also detects 284 tumors and 189 cases of NPH (although treatment is not included).

Table 3 suggests that treating NPH does not save any additional QALYs and indeed reduces overall quality-adjusted survival (174 QALYs); thus, in Figure 1 the best case scenario is to have fewer cases due to NPH. The overall cost, including the cost of the NPH operations, is £2,997,639 with no extra QALYs saved, giving a cost of £17,238 per QALY. A third strategy is to treat all patients with SDH or tumors at a total cost of £4,243,857; 213 QALYs are gained, but the cost per QALY is £19,983. The marginal cost of the additional 35 QALYs is £1,726,529 or £49,329 per added QALY. These strategies are presented together in Table 4.

The most QALYs were gained by a strategy of using CT scanning on all patients with dementia and treating those with SDH and tumors only. Treating NPH was found to reduce overall quality-adjusted survival in the model. Treating tumors gained only a small quantity of QALYs, and the expected increase in life expectancy after a successful operation was small. Thus, the marginal cost of treating brain tumors was very high. The most cost-effective strategy was to scan all patients but treat only those with SDH, giving a cost per QALY of £14,171, which is comparable to a number of routinely available but high-cost treatments. However, it may be that there are ethical objections to detecting tumors but denying treatment.

Sensitivity Analysis

The variables to which our model is most sensitive are the proportion of all cases of dementia that are reversible, the proportion of those reversibles cases that can

Table 3. Cost, Life-years Gained, and Cost per QALY Gained with Separate Surgical Strategies

Tumors				Subdural hematoma (SDH)				Normal pressure hydrocephalus (NPH)			
	Low	Baseline	High		Low	Baseline	High		Low	Baseline	High
Cost of screening by CT scans		£2,369,387		Cost of screening by CT scans		£2,369,387		Cost of screening by CT scans		£2,349,387	
Cost of all tumor operations		£1,726,529		Cost of all SDH operations		£147,942		Cost of all NPH operations		£480,310	
Total tumor costs (incl. CT)		£4,095,916		Total SDH costs (incl. CT)		£2,517,329		Total NPH costs (incl. CT)		£2,849,697	
Life-years gained		26		Life-years gained		695		Life-years gained		149	
Life-years lost		7		Life-years lost		4		Life-years lost		37	
Total benefit (ys)		18		Total benefit (ys)		691		Total benefit (ys)		112	
A: Total QALYs if untreated	28	43	57	A: Total QALYs if untreated	16	23	31	A: Total QALYs if untreated	149	224	299
QALYs if treated (improved)	31	36	41	QALYs if treated (improved)	175	200	225	QALYs if treated (improved)	105	120	135
QALYs if treated (died)	−1	−2	−3	QALYs if treated (died)	−1	−1	−2	QALYs if treated (died)	−7	−11	−15
QALYs if treated (no benefit)	22	44	66	QALYs if treated (no benefit)	1	2	4	QALYs if treated (no benefit)	56	112	168
B: Total QALYs if treated	52	78	104	B: Total QALYs if treated	175	201	227	B: Total QALYs if treated	154	221	288
QALY benefit of treatment (B-A)[a]	23	35	47	QALY benefit of treatment (B-A)[a]	160	178	196	QALY benefit of treatment (B-A)[a]	4	−4	−11
Cost per QALY with tumor treatment only	£180,535	£117,901	£87,532	Cost per QALY with SDH treatment only	£15,765	£14,171	£12,870	Cost per QALY with NPH treatment only	£762,605	−£762,605	−£254,202

[a] These figures were calculated on an exact mathematical model. While costs are exact, benefits are here rounded to the nearest "whole patient" or complete QALY.

Table 4. Possible Treatment Strategies

Strategy	QALYs gained	Total cost	Cost/QALY
(A) Screen all patients with dementia, only treat SDH	178	£2,517,329	£14,171
(B) Screen all patients with dementia, only treat SDH and NPH	174	£2,997,639	£17,238
(C) Screen all patients with dementia, only treat SDH and tumors	217	£4,243,857	£19,983

Abbreviations: SDH = subdural hematoma; NPH = normal pressure hydrocephalus; QALY = quality-adjusted life-years.

actually be detected by CT scanning, the future life span of the patients presenting for screening, and the cost of each CT scan (Figure 2).

The sensitivity analysis has only been applied to strategy A in Table 4. The current prevalence of dementia in Scotland has been estimated to be 9.3% in those over age 65. If the true prevalence is higher, then the cost per QALY of the different strategies will remain unchanged, and although additional life-years will be saved, total costs to the NHS will increase. If the prevalence is in fact 15%, then the total cost would rise to £4,060,208 per annum. At a prevalence of only 6.5%, the total cost would be £1,759,423.

The above calculation assumes a fully depreciated scanner. If a new scanner is used, the total cost rises to £4,271,374 at a cost per QALY of £24,046. As the cost per CT scanner is the most important element within the control of each commissioner, Figure 3 represents this effect. This figure is of particular importance to health care commissioners who do not have direct access to a CT scanner. The

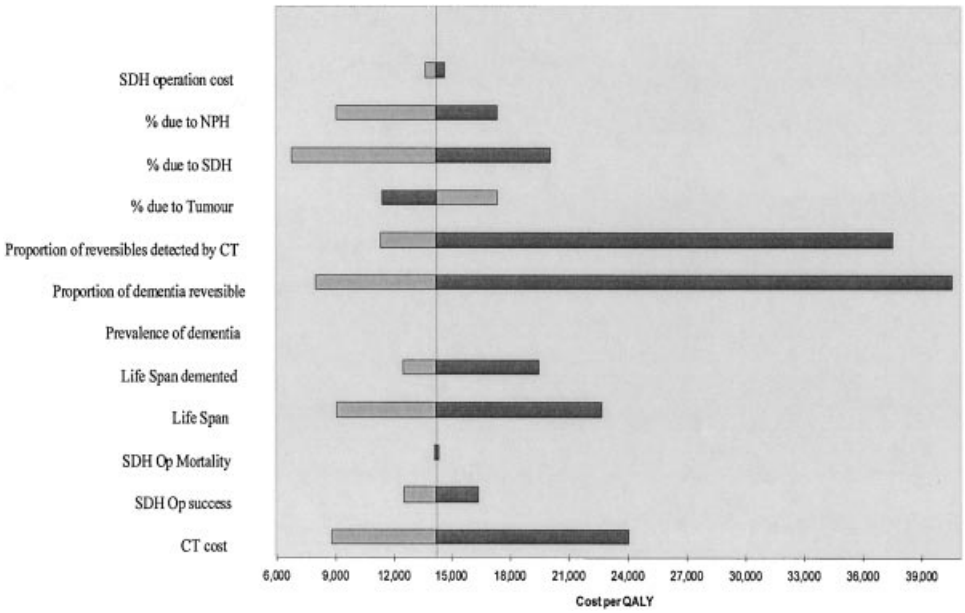

Figure 2. Sensitivity analysis.

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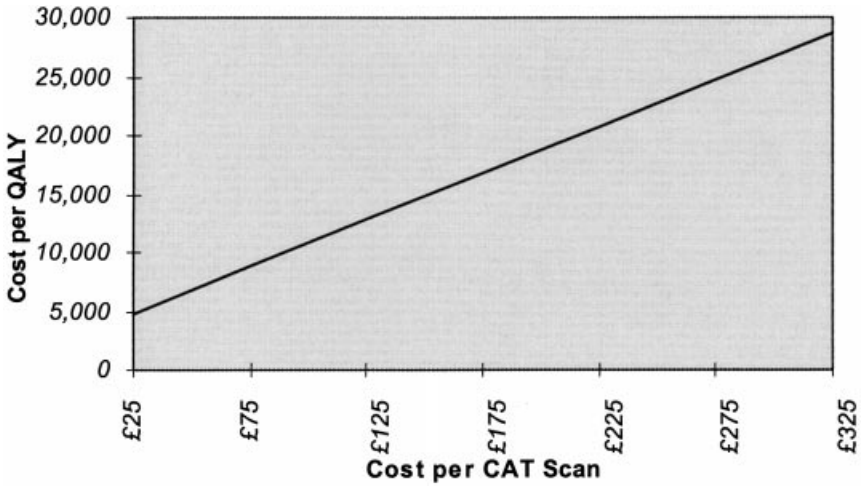

Figure 3. Sensitivity analysis—effect of scan cost.

total cost of transporting a demented patient to a scanner for investigation will make the marginal cost of such a strategy very high.

If we assume a younger average age (by means of a greater average life span at age 65 in our model), the cost per QALY is reduced. Increasing life span to 25 years (patients aged 56) reduces the cost per QALY to £9,070. Scanning older patients costs more per QALY saved, for example, at age 71 (with a life span of 10 years) and gives a cost per QALY of £22,674.

The extreme low and high estimates for our quality-of-life adjustments (Table 2) gave a variance of less than 9% from the baseline model.

DISCUSSION

The calculations above assume that without universal CT scanning in dementia, no cases of treatable structural lesions would be detected. In fact, all of these conditions commonly give rise to signs or symptoms that might raise diagnostic suspicion, leading to investigation and diagnosis. Overall it is likely that up to 50% of all cases might be detected, even in the absence of screening by CT scanning at presentation. If all cases detected and investigated on specific clinical grounds were treated, then the marginal benefit of CT scanning of all patients with dementia would be greatly reduced. If only 50% of cases were detected and treated as a result of CT scanning, the cost of the CT scans (£2,369,386 per annum) would remain, but the costs of treatment attributable to the scanning policy would be halved and the QALY benefit would also be halved. The marginal cost per QALY saved by the CT scanning policy would be £27,510.

Caution should be exercised when interpreting the above measures of cost-utility. The total annual cost of a countrywide program (A) has amounted to £2,517,329. In the absence of additional funding, other programs with a higher cost per QALY and equivalent total cost would need to be identified and stopped before the new program could be funded.

We can find no distinct age at which it becomes less cost-effective to perform routine CT scans for reversible causes of dementia. We have shown that the use of CT scans to screen patients over age 65 with dementia is an expensive procedure

with a high cost per QALY saved. The overall cost-effectiveness is highly dependent on the local availability and cost of CT scans. The cost-effectiveness of scanning also decreases with the age of the population under study. In the very elderly population the prevalence of dementia is over 20%, and scanning all cases would be a massive drain on resources. Both NPH and tumours are reported to be less common in this elderly group. The actual number of life-years gained by curing a patient in their 80s is much smaller than those to be gained in a younger patient; however, the value of each year may be correspondingly greater. On balance it would seem a very cost-inefficient use of resources to use CT on a very elderly patient with dementia unless there are clear signs of a structural lesion and the patient is clearly fit and willing to undertake a major operation. Local commissioners of care must decide whether such costs are justified.

It is clear from the literature review and from the model that it is only in the cases of SDH that there is a significant chance of improvement for most patients. The evidence of improvement in tumor cases is much less strong and, although individual patients may benefit, from the population perspective this is unlikely to justify the pain, suffering, and anxiety generated by undertaking complex, invasive neurosurgical procedures with mostly poor outcomes in frail, elderly, and confused patients. Although the treatment of NPH by shunting has been proposed, we have not found evidence of any overall benefit in the frail, confused elderly. Although individual case reports do demonstrate patients improving markedly after shunting, systematic review of the published literature appears to demonstrate an equal probability of spontaneous remission. This operation is not without risks and carries both a high mortality and a high postoperative morbidity, with many shunts subsequently being removed due to complications. We can find no evidence to support the use of shunting in senile dementia patients with dilated ventricles and therefore recommend that shunting should be offered only within a properly organized, multicenter, randomized controlled trial.

CT scanning can be a difficult and distressing procedure for a patient with senile dementia, although the great majority of patients lack insight. Relatives are frequently asked to consent to these procedures but have little or no understanding of what they involve or of the chances of positive outcome. Many of the procedures undertaken may be treating the needs of the relatives or the medical staff rather than the patient's needs.

It could be argued that though a patient is confused, does not know what is happening, and is less likely to value quantity of life, an additional benefit of diagnosing structural lesions is the value of a more accurate prognosis for relatives and caregivers. This review has found no evidence that CT scanning will lead to more accurate diagnosis or prognosis without clear clinical signs suggesting a structural lesion or cancer (34). CT scanning is of most value in recent onset or acute deterioration of dementia and those with unexplained or atypical neurologic findings.

This model has not quantified the harm done to elderly patients who have to undergo further investigations or treatment after false-positive CT scans. This negative effect is hard to quantify but should be considered where the potential benefit from scanning all patients is quite small.

There is an important ethical question over the care of patients who, by nature of their dementing illness, have no insight into their condition. These patients, although demented, may not actually be suffering and one must question whether it is reasonable to subject them to painful, distressing, and dangerous procedures

in an attempt to prolong life. Often such patients' condition seems more distressing to relatives and caregivers than to the patients themselves. This ethical debate is beyond the scope of this paper but should not be forgotten.

This model has only quantified the direct NHS costs of scanning and treatment. There are substantial local authority (community care) and societal costs in caring for the demented elderly. Purchasers will need to consider the costs of caring for treated and untreated demented patients. The annual cost of hospital care for a geriatric psychiatry patient is £33,540 (25). There may be a small saving in care costs for patients who are completely cured by treatment, and it is clear that there will be savings on caring for those who die during an operation. However, there will be increased costs for those for whom treatment is unsuccessful, leads to complications that require treatment, or leads to increased life span without improving quality of life.

CONCLUSIONS AND RECOMMENDATIONS

This study has considered whether the routine clinical use of CT scanning of all patients diagnosed as having dementia is worthwhile. Based on the above model and systematic literature review, routine CT scans for every demented patient cannot be supported. Indeed, more harm than good to patients could be caused by such an approach. In young patients, more than 20% of cases of dementia are likely to be due to reversible disease, and these patients should undergo investigation including CT scanning.

In the excitement of the chase we must not lose sight of the fact that almost all patients with dementia commencing over the age of 65 have irreversible disease, and our main concern must be to care for these demented patients and their families, not to search relentlessly for the needle in the haystack.

We recommend that commissioners of health care carefully consider the local costs of CT scanning. CT scanning should be limited to those patients where it is clearly clinically indicated by the signs and symptoms of the illness. A suggested general strategy is below (14):

CT scan demented patients only when:
(A) Age under 65[2]
OR
(B) Age 65 and over
AND
Onset less than 1 year
OR
Atypical presentation
OR
Rapid unexplained deterioration
OR
Unexplained focal neurological signs or symptoms
OR
History of recent (before onset) head injury
OR
Urinary incontinence or gait ataxia early in the illness.

NOTES

[1] All calculations for the model were done in a spreadsheet, thus any data in tables or figures is rounded to the nearest "whole person." A copy of the spreadsheet showing exact values is available from the authors.

[2] Clarfield and Larson (14) recommend under age 70, but this appears to be based only on evidence of the occurrence of SDH in patients under 70: 74% and 91.2%, from Black (4) and Luxon and Harrison (36), respectively.

REFERENCES

1. Aichner, F., Wagner, M., Kremser, C., et al. MR-imaging of non-Alzheimer's dementia. *Journal of Neural Transmission*, 1996, 47, 143–53.
2. Barclay, L. L., Zemcov, A., Blass, J. P., et al. Survival in Alzheimer's disease and vascular disease. *Neurology*, 1985, 35, 834–40.
3. Bergman, H., Chertkow, H., Wolfson, C., et al. HM-PAO (CERETEC) SPECT brain scanning in the diagnosis of Alzheimer's disease. *Journal of the American Geriatric Society*, 1997, 45, 15–20.
4. Black, D. W. Subdural haematoma: A retrospective study of the great neurologic imitator. *Postgraduate Medicine*, 1985, 78, 107–14.
5. Black, P. M. Idiopathic normal-pressure hydrocephalus. Results of shunting in 62 patients. *Journal of Neurosurgery*, 1980, 52, 371–77.
6. Black, R. J., Sharp, L., & Kendrick, S. K. (eds.). *Trends in cancer survival in Scotland, 1968–1990*. Edinburgh: ISD Publications, 1993, 54–55.
7. Bradshaw, J. R., Thomson, J. L. G., & Campbell, M. J. Occasional review: Computed tomography in the investigation of dementia. *British Medical Journal,* 1983, 286, 277–80.
8. Brooks, D. J. Functional imaging techniques in the diagnosis of non-Alzheimer dementias. *Journal of Neural Transmission*, 1996, 47, 155–67.
9. Buchpiguel, C. A., Mathias, S. C., Itaya, L. Y., et al. Brain SPECT in dementia. A clinical-scintigraphic correlation. *Arquivos de Neuro-Psiquiatria*, 1996, 54, 375–83.
10. Burns, A., Luthert, P., Levy, R., et al. Accuracy of clinical diagnosis of Alzheimer's disease. *British Medical Journal*, 1990, 301, 1026.
11. Butler, R. N., & Katzman, R. (eds.). *Alzheimer's disease—Senile dementia and related disorders: The role of NIA*. New York: Raven Press, 1978, 7.
12. Clarfield, A. M. The reversible dementias: Do they reverse? *Annals of Internal Medicine*, 1988, 109, 476–86.
13. Clarfield, A. M. Normal-pressure hydrocephalus: Saga or swamp? *JAMA*, 1989, 262, 2592–93.
14. Clarfield, A. M., & Larson, E. B. Should a major imaging procedure be required in the workup of dementia? An opposing view. *Journal of Family Practice*, 1990, 31, 405–10.
15. *Dementia touches everyone: A guide for trainers and trainees in general practice*, 1st ed. Stirling, Scotland: Dementia Services Development Centre. 1995.
16. Dietch, J. T. Computerized tomographic scanning in cases of dementia. *Western Journal of Medicine*, 1983, 138, 385–87.
17. Friedland, R. P. Normal pressure hydrocephalus and the saga of the treatable dementias. *JAMA*, 1989, 262, 2577–81.
18. Grossman, M., Mickanin, J., Onishi, K., et al. Progressive nonfluent aphasia: Language, cognitive, and pet measures contrasted with probable Alzheimer's disease. *Journal of Cognitive Neurosciences*, 1996, 8, 135–54.
19. Haar, F. L., Lott, T. M., & Nichols, P. J. The usefulness of CT scanning for subdural hematomas. *Neurosurgery*, 1977, 272–75.
20. Hier, D. B., Warach, J. D., Gorelick, P. B., et al. Predictors of survival in clinically diagnosed Alzheimer's disease and multi-infarct dementia. *Archives of Neurology*, 1989, 46, 1213–16.
21. Hodges, J. R., Ledingham, J. G. G., & Warrell, D. A. (eds.). *Oxford textbook of medicine*, 3rd ed. Oxford: Oxford University Press, 1996, 3965–71.

22. Hofman, A., Rocca, W. A., Brayne, C., et al. The prevalence of dementia in Europe: A collaborative study of 1980-1990 findings. *International Journal of Epidemiology*, 1991, 20, 736–48.
23. Homer, A. C., Honavar, M., Lantos, P. L., et al. Diagnosing dementia: Do we get it right? *British Medical Journal*, 1988, 297, 894–96.
24. Huckman, M. S. Normal pressure hydrocephalus: Evaluation of diagnostic and prognostic tests. *American Journal of Neuroradiology*, 1981, 2, 385–95.
25. Information and Statistics Division. *Scottish Health Service costs: Year ended 31st March 1996*. Edinburgh: National Health Service in Scotland, 1996.
26. Information and Statistics Division. *Scottish health statistics 1995*. Edinburgh: NHS (Scotland) 1996, 8.
27. Jagust, W. J., & Eberling, J. L. MRI, CT, SPECT, PET: Their use in diagnosing dementia. *Geriatrics*, 1991, 46, 28–35.
28. Jellinger, K. Pathological correlates of dementia in Parkinson's disease. *Archives of Neurology*, 1987, 44, 690–91.
29. Jobst, K. A., Hindley, N. J., King, E., et al. The diagnosis of Alzheimer's disease: A question of image? *Journal of Clinical Psychiatry*, 1994, 55, 22–31.
30. Jorm, A. F., Korten, A. E., & Henderson, A. S. The prevelance of dementia: A quantitative integration of the literature. *Acta Psychiatrica Scandinavica*, 1987, 76, 465–79.
31. Katzman, R. Should a major imaging procedure (CT or MRI) be required in the workup of dementia? An affirmative view. *Journal of Family Practice*, 1990, 31, 401–10.
32. Kramer, S. I., & Reifler, B. V. Depression, dementia and reversible dementia. *Clinics in Geriatric Medicine*, 1992, 8, 289–97.
33. Larson, E. B., Reifler, B. V., Featherstone, H. J., et al. Dementia in elderly outpatients: A prospective study. *Annals of Internal Medicine*, 1984, 100, 417–23.
34. Larson, E. B., Reifler, B. V., Sumi, S. M., et al. Diagnostic tests in the evaluation of dementia: A prospective study of 200 elderly outpatients. *Archives of Internal Medicine*, 1986, 146, 1917–22.
35. Ludbrook, A. Using economic appraisal in health services research. *Health Bulletin*, 1990, 48, 81–90.
36. Luxon, L. M., & Harrison, M. T. G. Chronic subdural haematoma. *Quarterly Journal of Medicine*, 1979, 189, 43–53.
37. Marsden, C. D., & Harrison, M. J. G. Outcome of investigation of patients with presenile dementia. *British Medical Journal*, 1972, 2, 249–52.
38. Martin, D. C., Miller, J., Kapoor, W., et al. Clinical prediction rules for computed tomographic scanning in senile dementia. *Archives of Internal Medicine*, 1987, 147, 77–80.
39. Masterman, D. L., Mendez, M. F., Fairbanks, L. A., et al. Sensitivity, specificity, and positive predictive value of technetium 99-HMPAO SPECT in discriminating Alzheimer's disease from other dementias. *Journal of Geriatric Psychiatry and Neurology*, 1997, 10, 15–21.
40. Mattman, A., Feldman, H., Forster, B., et al. Regional HmPAO SPECT and CT measurements in the diagnosis of Alzheimer's disease. *Canadian Journal of Neurological Sciences*, 1997, 24, 22–28.
41. Molsa, P. K., Marttila, R. J., & Rinne, U. K. Survival and cause of death in Alzheimer's disease and multi-infarct dementia. *Acta Neurologica Scandinavica*, 1986, 74, 103–07.
42. Molsa, P. K., Paljarvi, L., Rinne, J. O., et al. Validity of clinical diagnosis in dementia: A prospective clinicopathological study. *Journal of Neurology Neurosurgery and Psychiatry*, 1985, 48, 1085–90.
43. Mortimer, J. A., & Schuman, L. M. *The epidemiology of dementia*. New York: Oxford University Press, 1981, 99.
44. Mulrow, C. D., Feussner, J. R., Williams, B. C., et al. The value of clinical findings in the detection of NPH. *Journal of Gerontology*, 1987, 42, 277–79.
45. Needham, M. R. Controversies in cost-effective imaging: A primer for physicians and utilization managers. *Comprehensive Therapy*, 1997, 23, 345–48.

46. Newberg, A. B., & Alavi, A. The study of neurological disorders using positron emission tomography and single photon emission computed tomography. *Journal of Neurological Sciences*, 1996, 135, 91–108.
47. Nordberg, A. Application of PET in dementia disorders. *Acta Neurologica Scandinavica*, 1996, 168, 71–76.
48. Raskind, R., Glover. M. J., & Weiss, S. R. Chronic subdural hematoma in the elderly: A challenge in diagnosis and treatment. *Journal of the American Geriatric Society*, 1972, 20, 330–34.
49. Reding, M., Haycox, J., & Wigforss, K. Follow up of patients referred to a dementia service. *Journal of the American Geriatric Society*, 1984, 32, 265–69.
50. Riisoen, H., & Fossan, G. O. How shall we investigate dementia to exclude intracranial meningiomas as cause? An analysis of 34 patients with meningiomas. *Age and Ageing*, 1986, 15, 29–34.
51. Roberts, M. A., & Caird. F. I. The contribution of computerized tomography to the differential diagnosis of confusion in elderly patients. *Age and Ageing*, 1990, 19, 50–56.
52. Rocca, W. A., Hofman, A., Brayne, C., et al. Frequency and distribution of Alzheimer's disease in Europe: A collaborative study of 1980-1990 prevalence findings. *Annals of Neurology*, 1991, 30, 381–90.
53. Rocca, W. A., Hofman, A., Brayne, C., et al. The prevalence of vascular dementia in Europe: The facts and fragments from 1980-1990 studies. *Annals of Neurology*, 1991, 30, 817–24.
54. Rosser, R., & Kind, P. A. A scale of valuations of states of illness: Is there a social consensus? *International Journal of Epidemiology*, 1978, 7, 347–58.
55. Rubenstein, L. Z. Reversible dementia. In J. C. Beck, moderator. Dementia in the elderly: The silent epidemic. *Annals of Internal Medicine*, 1982, 97, 231–41.
56. Salmon, J. H. Adult hydrocephalus. Evaluation of shunt therapy in 80 patients. *Journal of Neurosurgery*, 1972, 37, 423–28.
57. Scheltens, P., Launer, L. J., Barkhof, F., et al. The diagnostic value of magnetic resonance imaging and technetium 99m-HMPAO single-photon-emission computed tomography for the diagnosis of Alzheimer disease in a community-dwelling elderly population. *Alzheimer Disease and Associated Disorders*, 1997, 11, 63–70.
58. Simon, D. G., & Lubin, M. F. Cost-effectiveness of computerized tomography and magnetic resonance imaging in dementia. *Medical Decision Making*, 1985, 5, 335–54.
59. Smith, J. S., & Kiloh, L. G. The investigation of dementia: Results in 200 consecutive admissions. *Lancet*, 1981, 824–27.
60. Talbot, P. R., & Testa, H. J. The value of SPECT imaging in dementia. *Nuclear Medicine Communications*, 1995, 16, 425–37.
61. Tierney, M. C., Fisher, R. H., Lewis, A. J., et al. The NINCDS-ADRDA Work Group criteria for the clinical diagnosis of probable Alzheimer's disease: A clinicopathologic study of 57 cases. *Neurology*, 1988, 38, 359–64.
62. Udvarhelyi, G. B., Wood, J. H., James, E. A. J., et al. Results and complications in 55 shunted patients with normal pressure hydrocephalus. *Surgical Neurology*, 1975, 3, 271–75.
63. Vanneste, J., Augustijn, P., Dirven, C., et al. Shunting normal-pressure hydrocephalus: Do the benefits outweight the risks? A multicenter literature review. *Neurology*, 1992, 42, 54–59.
64. Wang, H. S., & Katzman, R. (eds.). *Prognosis in dementia and related disorders in the aged*. New York: Raven Press, 1978, 7.
65. Weichert, H. C., Lohr, E., Grote, W., et al. Limitations of computerised tomography in the diagnosis of subdural haematoma. *Neuroradiology*, 1978, 16, 469–71.
66. Wells, C. E. Chronic brain disease: An overview. *American Journal of Psychiatry*, 1978, 135, 1–11.