A systematic review of teleradiology for remote neurosurgical evaluation of patients in facilities without neurosurgery specialists

by

Dinsie B. Williams

A thesis submitted in conformity with the requirements for the degree of Master of Science in Health Technology Assessment & Management
Department of Health Policy Management and Evaluation, Faculty of Medicine
University of Toronto

© Copyright by Dinsie B. Williams (2009)
ABSTRACT

Background: Teleradiology is currently being explored to enhance services for patients seeking emergency neurosurgical diagnoses in Ontario, Canada.

Design: Systematic review of literature and cost-consequence analysis.

Data sources: Medline, Embase, Cochrane, and Database of Abstracts of Reviews of Effects.

Methods: Studies published between 1950 and 2008 describing remote consultations for neurosurgical assessments were retrieved. Two reviewers selected studies through multi-staged content screening and extracted data.

Results 12 of 3765 studies met the inclusion criteria: two were randomized controlled trials and ten were case series. Teleradiology [88% (207/236)] and video-conferencing [89% (213/239)] consultations produced higher diagnostic accuracy than telephone consultations [64% (150/235), p<0.001]. Savings varied by location and were based on avoided costs for ground and air transportation and hospitalization.
Conclusions: There is limited evidence of clinical benefit of teleradiology. Savings associated with reduction in patient transfer rates depend on transportation mode and may be attenuated by higher operational costs.
ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr. Andreas Laupacis for his guidance, encouragement and patience over the past two years. I will remain indebted to him for all the time he spent meticulously reviewing my work, extracting data and providing me with invaluable comments. Thanks to the other members of my thesis committee: Dr. Les Levin (Head, Medical Advisory Secretariat and Senior Medical, Scientific and Health Technology Advisor to the Ontario Ministry of Health and Long-Term Care), and Alan Moody (Associate Scientist, Sunnybrook Health Sciences Centre). I sincerely appreciate the time, attention, and support they gave to me.

Thanks to Kris Bailey (Executive Director) and Vanessa Alexis (Program Manager) of CritiCall Ontario for providing me with data.

My thanks also go to Nancy Sikich of the Medical Advisory Secretariat to the Ontario Ministry of Health and Long-Term Care for meeting with me and providing me with quality assessment tools, Laure Perrier of the Faculty of Medicine at the University of Toronto for her advice and help with the literature searches, Rumona Dickson and Dr. Wendy Ungar of the Ulysses Program for guiding me through the early stages and Yeesha Poon for reviewing articles and for being there throughout the process. Thanks to my mother, siblings, extended family and my fabulous friends for providing moral support when I needed it. Finally, I would like to express my gratitude to the THETA Collaborative for providing me with a travel and accommodation bursary to attend classes in
Rome and Barcelona, and to Hayes Inc. for fostering a flexible work environment that allowed me to pursue this opportunity.
# TABLE OF CONTENTS

ABSTRACT ......................................................................................................................II

ACKNOWLEDGEMENTS ..............................................................................................IV

TABLE OF CONTENTS .................................................................................................VI

LIST OF TABLES ........................................................................................................VIII

LIST OF FIGURES ........................................................................................................IX

LIST OF FIGURES ........................................................................................................IX

LIST OF APPENDICES ................................................................................................X

GLOSSARY ...................................................................................................................XI

EXECUTIVE SUMMARY ..............................................................................................1

1. INTRODUCTION .......................................................................................................3

   1.1 Policy Questions ....................................................................................................3

2. BACKGROUND .........................................................................................................5

   2.1 Clinical applications and target group .................................................................5

   2.2 Remote consultation ............................................................................................5

   2.3 Patient pathways and clinical outcomes ...............................................................9

   2.4 Patient categories ...............................................................................................11

   2.5 Technology and current patterns of use ...............................................................12

   2.6 Previous reviews ...............................................................................................15

3. OBJECTIVES ...........................................................................................................20

   3.1 Research questions .............................................................................................21

4. METHODOLOGY .....................................................................................................22

   4.1 Search strategy ....................................................................................................22

   4.2 Study inclusion criteria .......................................................................................22

   4.3 Study exclusion criteria .......................................................................................25

   4.4 Retrieval of records ............................................................................................25

   4.5 Quality assessment .............................................................................................26

   4.6 Data extraction ....................................................................................................28

   4.7 Data synthesis ....................................................................................................29

5. RESULTS ..................................................................................................................30

   5.1 Search results .....................................................................................................30

   5.2 Study designs .....................................................................................................31

   5.3 Provider profiles .................................................................................................33
LIST OF TABLES

Table 1 – Study characteristics (in alphabetical order of first author’s last name) .................. 33
Table 2 – Provider profiles ........................................................................................................ 34
Table 3 – Patient characteristics by study .................................................................................. 36
Table 4 – Answers to quality assessment questions ................................................................. 45
Table 5 – Quality assessment of studies comparing the impact of teleradiology to telephone on
remote consultations for patients in need of urgent neurosurgical evaluation (GRADE Working
Group, 2004) .......................................................................................................................... 46
Table 6 – Proportion of patients with unfavourable clinical outcomes (including death) .......... 53
Table 7 – Morbidity rates for teleradiology, telephone and video-conferencing consultations, one
month and six months after admission ..................................................................................... 54
Table 8 – Mortality rates for teleradiology, telephone and video-conferencing consultation, one
month and six months after admission ..................................................................................... 55
Table 9 – Proportion of patients transferred from referring hospitals to NSUs ....................... 58
Table 10 – Proportion of patients unnecessarily transferred from referral hospitals ............... 60
Table 11 – Average response times (minutes) .......................................................................... 61
Table 12 – Teleradiology costs ($, Canadian dollars) ................................................................. 67
Table 13 – Total air transportation and hospitalization costs avoided by locally hospitalizing
patients in teleradiology cohorts ($, Canadian dollars) ............................................................ 68
Table 14 – Difference in air transportation and ground transportation costs per patient ($,
Canadian dollars) .................................................................................................................... 69
Table 15 – Costing chart for fees and other direct costs associated with patients requiring
neurosurgical assessments ........................................................................................................ 80
Table 16 – Costing chart for transportation and hospitalization of patients requiring neurosurgical
assessments ............................................................................................................................... 82
LIST OF FIGURES

Figure 1 – Ontario emergency telephone consultation process flow ........................................... 7
Figure 2 – Hypothetical remote consultation process flow with teleradiology .............................. 8
Figure 3 – Patient pathways ..................................................................................................... 10
Figure 4 – Patient categories .................................................................................................. 12
Figure 5 – Search results ......................................................................................................... 31
Figure 6 – Distribution of patient characteristics ...................................................................... 37
Figure 7 – Limits on impact of teleradiology on patient transfer rates .................................... 58
LIST OF APPENDICES

Appendix A – Search parameters.................................................................89
Appendix B – Quality assessment checklists..................................................90
Appendix C – Data extraction tables..............................................................91
# GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATM</td>
<td>Asynchronous transfer mode</td>
</tr>
<tr>
<td>CASP</td>
<td>Critical Appraisal Skills Programme</td>
</tr>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
</tr>
<tr>
<td>GCS</td>
<td>Glasgow Coma Scale/Score</td>
</tr>
<tr>
<td>GOS</td>
<td>Glasgow Outcome Scale/Score</td>
</tr>
<tr>
<td>ICES</td>
<td>Institute for Clinical Evaluative Services</td>
</tr>
<tr>
<td>ICP</td>
<td>Intracranial Pressure</td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Services Digital Network</td>
</tr>
<tr>
<td>LHIN</td>
<td>Local Health Integrated Network</td>
</tr>
<tr>
<td>MOHLTC</td>
<td>Ministry of Health and Long-Term Care</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>NORTH</td>
<td>Northern Ontario Telehealth Network</td>
</tr>
<tr>
<td>NSU</td>
<td>Neurosurgical Unit</td>
</tr>
<tr>
<td>PACS</td>
<td>Picture Archiving and Communications Systems</td>
</tr>
<tr>
<td>QUOROM</td>
<td>Quality of Reporting of Meta-analyses</td>
</tr>
<tr>
<td>RC</td>
<td>Referring Centre</td>
</tr>
<tr>
<td>RP</td>
<td>Referring Physician</td>
</tr>
<tr>
<td>SPECT</td>
<td>Single Positron Emission Computed Tomography</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

It is often the responsibility of general physicians and emergency department physicians to assess, diagnose and manage patients in need of urgent neurosurgical care in non-specialty facilities in Ontario. Under certain circumstances the general and emergency department physicians use a telephone-based, remote consultation referral system to request assistance from neurosurgery specialists based at neurosurgical centres.

One major shortfall of the telephone consultation process is that it does not allow physicians to transmit radiographic images. Neurosurgery specialists depend on these images when diagnosing certain neurosurgical conditions. Without accurate or timely interpretation of radiographic images, most neurosurgery-related diagnoses are incomplete and may lead to unfavourable clinical outcomes ranging from severe disability to death. Teleradiology is being considered by the Ontario Ministry of Health and Long-Term Care as an option for transmitting images and facilitating remote consultations.

A systematic review was done to evaluate the effectiveness of teleradiology in remote neurosurgical consultations. The results indicate that:

1. The available evidence is inadequate to either support or oppose the use of teleradiology for neurosurgical consultations within Ontario
2. The impact of teleradiology on patient transfer rates may have been overestimated in some studies
3. The extent to which teleradiology can impact clinical and organizational outcomes is limited
4. Teleradiology cannot be readily linked directly to primary clinical outcomes such as morbidity and mortality.

In light of the findings of this review and the diffusion pressures surrounding the use of teleradiology, decision-makers should consider being actively involved in managing the introduction of the technology into the neurosurgical consultation process. There is ample opportunity to gather primary data during the early stages of implementation in Ontario and facilitate the establishment of a sustainable network within the province.
1. **INTRODUCTION**

1.1 **Policy Questions**

It is often the responsibility of general physicians and emergency department physicians to assess, diagnose and manage patients in need of urgent neurosurgical care in non-specialty facilities in Ontario. In June 2005, the Institute for Clinical Evaluative Services (ICES) published a report suggesting that teleradiology (“tele-imaging”) could be used to increase patients’ access to neurosurgery specialists (Tepper et al., 2005). As of December 31, 2005, sixty-seven (67) neurosurgery specialists were licensed to practise in Ontario and only thirteen (13) hospitals provided neurosurgical care. Four of the hospitals were community-based and were not equipped to provide care for complex cases. In December 2007, a panel of neurosurgery experts made a recommendation to augment clinical expertise in the province of Ontario by introducing criteria for requesting neurosurgical consultations and protocols for treating minor head injuries in emergency departments (Rutka et al., 2007). The panel also supported the development of a neurosurgical teleradiology (“image transfer”) system as a way of improving access, reducing unnecessary transfers, and reducing wait times for diagnosis and treatment of patients seeking neurosurgical care in Ontario. In-depth analysis is required to ensure proper implementation of these recommendations.

Although telemedicine has been successfully applied in clinical areas such as pathology, dermatology, and home healthcare, it is not clear how the technology will affect transfer rates, response times and clinical outcomes for patients
seeking neurosurgical assessments in Ontario. Furthermore, the operational resources required to staff, equip and maintain a teleradiology network in Ontario (for use exclusively to manage patients requiring neurosurgical care) are undocumented but are expected to be substantial. In 2005 alone, the Ministry of Health and Long-Term Care (MOHLTC) reported investing $6.3 million to upgrade all existing telemedicine and teleradiology equipment across Ontario (Government of Ontario News Release, 2005).

In order to ensure successful implementation of a teleradiology network for neurosurgery, the MOHLTC would need to assess the associated organizational, clinical and financial benefits. Several questions need to be answered. How many patients will have better quality access to a neurosurgery specialist because of teleradiology? How much faster will patients receive diagnoses? Will patient outcomes, such as morbidity and mortality rates, improve? Will patients be better prepared prior to being transported? How many unnecessary transfers can be avoided? What are the costs associated with implementing and maintaining a dedicated teleradiology network?

A systematic review of published literature on existing teleradiology networks is expected to provide the MOHLTC with insight into the impact teleradiology has on neurosurgical care.
2. BACKGROUND

2.1 Clinical applications and target group

The neurosurgeons who actively practise in the province of Ontario are currently resident in 14 neurosurgical units (NSUs). They serve a population of approximately 12,900,000 in an area that spans just over 1 million square kilometres (Statistics Canada 2009; Government of Ontario Website, 2009). It would be impractical for the neurosurgeons to travel away from the NSUs to assess and triage every patient in-person, particularly those admitted at peripheral medical facilities that do not have neurosurgical expertise. Instead, general and emergency department physicians at peripheral hospitals use a telephone-based, remote consultation system to communicate with neurosurgical experts based at NSUs.

2.2 Remote consultation

Between April 2008 and March 2009, CritiCall Ontario, the 24-hour telephone-based emergency referral service, processed 3146 emergent calls for remote neurosurgical consultations from community-based hospitals and facilitated 1546 referrals or transfers (49% of calls) to NSUs (CritiCall Ontario data, 2009). Six patients out of 1546 (0.4%) were referred to Winnipeg Health Sciences in Manitoba and 122 out of 1546 (7.9%) were referred to the United States.

---

a Since 2005, William Osler Health Centre as been added at the Brampton Civic Hospital in Brampton, Ontario, bringing the total number to 14.

b These calls exclude calls identified as ‘spinal’ in the CritiCall database.
There are no clinical practice guidelines for neurosurgical referrals in Ontario. However, physicians generally follow a process outlined by the CritiCall telephone referral service as shown in Figure 1. When a patient presents to a peripheral facility, a general or emergency physician (otherwise identified as a referring physician (RP)) establishes a preliminary diagnosis and a preliminary management plan for the patient. The RP is further responsible for establishing whether a patient can be locally treated or requires assessment and treatment by a specialist. The diagnosis is typically based on a combination of an assessment of the patient’s neurological status (vital signs, pupil size, light reflexes, and motor deficit) at admission, radiographic images (CT or MRI) and other clinical history. The management plan includes procedures to stabilize and treat the patient at the peripheral facility for the long-term or temporarily until a specialist is contacted.

If the patient is considered to be acutely ill, the referring physician makes a request for remote consultation with a neurosurgery specialist or team via a telephone call to CritiCall. The physician provides CritiCall with the neurological evaluation (excluding actual radiographic images) and clinical history of the patient. CritiCall connects the referring physician with a neurosurgery specialist or team practising out of an NSU with capacity. The physicians then discuss the patient’s clinical data over the phone. Information on additional diagnostic tests, including radiographic exams is shared verbally. The neurosurgery specialist (or team) then proceeds to confirm or update the preliminary diagnosis. Both teams of physicians are then responsible for updating the patient’s management plan (if
applicable) and assigning the patient to local admission or transfer to an NSU. Those patients who could benefit from advanced care are transferred to an NSU under appropriate supervision.

Figure 1 – Ontario emergency telephone consultation process flow

One major shortfall of the telephone consultation process is that it does not allow physicians to transmit radiographic images. Unfortunately, neurosurgical specialists depend on these images when diagnosing certain neurosurgical conditions. Without accurate or timely interpretation of radiographic images, most neurosurgery-related diagnoses are incomplete and may lead to unfavourable clinical outcomes ranging from severe disability to death (Poon et al., 1998). With telephone consultations, neurosurgery specialists have to rely on verbal or written transcripts of image interpretations by referring physicians or
radiologists who are resident at the referring centres. Some transcripts may incorrectly or incompletely convey radiographic findings. Advanced technology, such as teleradiology, may be used to facilitate the consultation process and minimize the number of unfavourable outcomes.

Teleradiology involves using telecommunications to transmit images over long distances for the purpose of diagnosis. The process used for remote consultation with teleradiology is similar to that used with the telephone. Figure 2 shows a hypothetical process including additional steps associated with teleradiology for requesting and reviewing images. Remote neurosurgical consultations are well-suited to teleradiology because the diagnosis process typically involves urgent evaluation of radiographic images.

**Figure 2 – Hypothetical remote consultation process flow with teleradiology**

Key: CritiCall=CritiCall Ontario Referral Service; RP=referring physician
2.3 Patient pathways and clinical outcomes

There are three possible pathways that patients follow after the preliminary assessment. As shown in Figure 3, patients in arm A are managed and treated locally, patients in arm B are managed in consultation with specialists and treated locally at a peripheral facility, while patients in arm C are managed in consultation with specialists and transferred to neurosurgical facilities for treatment. One of the underlying assumptions about remote consultations is that input from specialists has an impact on the clinical outcomes of patients. Specifically, the proportion of unfavourable outcomes in arm B \( (U_B/P_B) \) is expected to be lower than in arm A \( (U_A/P_A) \) for patients with similar prognoses. Furthermore, the proportion of unfavourable outcomes in arms B \( (U_B/P_B) \) and C \( (U_C/P_C) \) are expected to change with the type of consultation process (telephone, teleradiology or video-conferencing) used. It is unreasonable to compare outcomes of patients in arm C with either of arms A or B as patients in arm C will generally suffer from more severe conditions that require advanced care.
Figure 3 – Patient pathways

General or emergency physicians assess patients at peripheral facilities

Physicians develop management plans at peripheral hospital **without consulting** with specialists

**A**

Patients admitted to peripheral facilities, \( P_A \)

Favourable outcomes, \( F_A \)

Unfavourable outcomes, \( U_A \)

**B**

Patients admitted to peripheral facilities, \( P_B \)

Favourable outcomes, \( F_B \)

Unfavourable outcomes, \( U_B \)

**C**

Patients transferred to neurosurgical units, \( P_C \)

Favourable outcomes, \( F_C \)

Unfavourable outcomes, \( U_C \)
2.4 Patient categories

Patients requiring neurosurgical assessments can be placed into 3 categories according to their need for consultation (Figure 4). The first category of patients consists of those that can be adequately assessed and managed by general physicians without consultation. Practically all of these patients will be hospitalized at the peripheral hospital as specialists would need to be involved if a patient was being transferred to an NSU. The number of patients in this category depends on the skill-set of the general physicians at the peripheral facilities and the presenting conditions of the patients. The existence of a telephone or teleradiology network will have virtually no effect on the management of these patients.

The remaining patients can be assigned to two categories. Some would fall into category 2 where specialists can adequately perform remote assessments and develop management plans through telephone consultations. The number of patients in this category depends on the ability of the referring physician to verbally relay radiographic information to a specialist over the phone and the specialist’s level of comfort at reaching a conclusion based on the available information. A portion of these patients would be assigned to the peripheral facility while the rest would be assigned to transfer to an NSU. Radiographic images are not required for these patients, therefore, if a teleradiology network existed, their management plans would remain virtually unchanged.

The third category consists of patients for whom specialists require radiographic images for adequate diagnosis and management. According to the study by
Fery-Lemonnier et al. general physicians transmitted images for as few as 25% of neurosurgical cases to specialists when teleradiology was available (Fery-Lemonnier et al., 1996). In the absence of teleradiology, some of these patients would be incorrectly assigned to be hospitalized at peripheral facilities (category 3a) while others would be incorrectly assigned to be transferred to NSUs (category 3b). The impact of introducing teleradiology is a function of the magnitude and importance of the incorrect assignments.

**Figure 4 – Patient categories**

1. RP can assess and manage these patients without consulting a specialist.
2. RP can assess and manage these patients with telephone consultation.
3a. Specialists require images to adequately assess these patients. Patients would be incorrectly assigned to peripheral facilities in absence of teleradiology.
3b. Specialists require images to adequately assess these patients. Patients would be incorrectly assigned to NSU in absence of teleradiology.

Key: GP=general physicians; EP=emergency physicians; NSU=neurosurgeons

### 2.5 Technology and current patterns of use

Teleradiology was originally implemented in the 1970s to enable physicians to electronically transfer images from geographically remote locations to specialists in advanced care centres for the purpose of diagnosis and/or treatment planning.
Links between primary care centres in rural areas and urban centres have since proliferated, although several systems have gone defunct in a short period of time while others remain without showing adequate proof of tangible benefit (Robb, 1997). A teleradiology network may allow non-specialist physicians to transfer images acquired at their institution over electronic media and have the images interpreted by neurosurgeons (or otherwise qualified specialists) at distant locations. Unlike other clinical disciplines that are typically covered by the term telemedicine, teleradiology specifically refers to the transfer of digitized radiographic images and peripheral clinical information. Radiographic images include those acquired by x-ray, computed tomography (CT), ultrasound (U/S), magnetic resonance imaging (MRI), positron emission tomography (PET) and single photon emission computed tomography (SPECT). Currently, neurosurgeons primarily use CT and MRI images for diagnoses.

A teleradiology system has an acquisition and transmission station at the peripheral facility, and a receiving and reviewing station at a specialist/tertiary care centre. At the front end, a trained radiographer or technologist acquires and prepares radiographic images for transmission. Contemporary systems use Internet Protocol or Integrated Services Digital Network (ISDN) lines to transmit data at rates of 14 kilobits per second or higher (Bailes et al., 1997). The receiving station has a display system where a radiologist (or trained specialist such as a neurosurgeon or neurosurgery resident) interprets the images. A typical display system includes a picture archiving and communication system.
and a personal computer with a graphic monitor. Verbal communication between
the specialist and the referring physician generally takes place over the
telephone. Alternatively, physicians may use video-conferencing to communicate
and display images.
Teleradiology systems are installed by third-party vendors using components
from various manufacturers of picture archiving and communications systems
(PACS), personal computers, and imaging workstations. Maintenance
procedures for teleradiology components are consistent with those of
telecommunications systems. There is no single vendor with significant market
share in installing and maintaining teleradiology systems worldwide. The costs
reported in the published literature vary as there is a wide range of components
used in teleradiology systems.
There are two primary approaches to implementing teleradiology, with each
approach giving rise to different sets of issues. The first approach is one in which
large, urban hospitals use teleradiology primarily as a creative means of reducing
costs and workload of on-site radiologists. In this model, hospitals send
radiographic images to smaller, specialized centres for on-demand review. The
centres may be located locally or in a different country. Physicians in hospitals
located in areas without specialists tend to embrace a different approach – one
that is more relevant to the previously stated policy question. In particular, rural
hospitals, as Lee et al. reported in 1998, primarily use teleradiology to address
the lack of access to specialists (Lee et al., 1998). Physicians in these rural
hospitals (or in any facility without a resident specialist) may request
consultations with specialists who work out of geographically distant hospitals or specialist units located in urban areas.

Although specific indications for use of teleradiology in remote neurosurgical consultations have not been described in Ontario, the province has some relevant precursor services in place. In 2006, the Southwestern Ontario Telehealth Network, the Eastern Ontario Telehealth Network and the Northern Ontario Telehealth Network (NORTH) collectively provided general telemedicine services to over 200 sites. The teleradiology component of the NORTH network served 13 sites (Ho and Jarvis-Selinger, 2006; Ontario Telemedicine Network website, 2009). The Ontario Association of Radiologists approved a new Teleradiology Standard in June 2007 based on the American College of Radiology’s Technical Standard for Teleradiology (Ontario Association of Radiologists, 2007). In their 2007/2008 annual report, CritiCall Ontario reported collaborating with the Neurosurgical Expert Panel to pilot a neurosurgical referral service that includes a teleradiology (“image transfer”) system (CritiCall website, 2009). Details of the service have not yet been published. A review of existing teleradiology networks will be useful in strengthening the plan for implementing such a teleradiology network for remote neurosurgical consultations.

2.6 Previous reviews

A search of the Cochrane Database of Reviews and the Database of Abstracts and Reviews of Effect using keywords: telemedicine or teleradiology combined
with *neurosurgery, neurosurgical* and *rural*, produced six reviews (Currel et al., 2000).

In a review of telemedicine published in 2001, Roine *et al.* made reference to articles published between 1966 and 2000 (Roine *et al.*, 2001). Thirteen articles on teleradiology were included of which five were specific to neurosurgical consultations (Spencer *et al.*, 1991; Fery-Lemonnier *et al.*, 1996; Bailes *et al.*, 1997; Goh *et al.*, 1997a; Heautot *et al.*, 1999). An additional study was found that described a cost analysis of a teleradiology system used for emergency cases (Stoeger *et al.*, 1997). In that study only sixty-nine percent of the cases were neurosurgical. Teleradiology changed patient management in 81% of cases in one study in which an image transfer system was used to link a neuroradiology centre to six referring hospitals (Roine *et al.*, 2001) and reduced the number of inter-hospital transfers for neurosurgical emergencies in another (Eljamel and Nixon, 1992). Unnecessary transfers of neurosurgical patients were reduced by 21% compared to telephone consultation in one study (Goh *et al.*, 1997a) and avoided in 16-50% of cases in another (Heautot *et al.*, 1999). In one study, 67% (67/100) of patients needing neurosurgical care were transferred when teleradiology was used (Bailes *et al.*, 1997). Finally, one study found that the cost of avoided patient transfers was high as images were transmitted in only 25% of neurosurgical cases (Spencer *et al.*, 1991). The review authors concluded that “relatively convincing evidence of effectiveness was found for teleradiology, teleneurosurgery, telepsychiatry and transmission of echocardiographic images”.

Although the authors clearly defined their process for retrieving and extracting
evidence, their conclusions are based on a small number of disparate studies. It is particularly unlikely that conclusions could be made about effectiveness. The same group of authors published a systematic review in 2002 with Hailey as the main author, using the same body of evidence (Hailey et al., 2002). An update of the 2002 report was published in 2004 in which the authors indicated that of 46 articles published between January 2000 and June 2002 only one assessed the impact of teleradiology on neurosurgical cases. The authors stated that in this one study, it was unclear whether teleradiology improved outcomes in neurosurgical cases (Poon et al., 2001; Hailey et al., 2004). Benger et al. (2002), reviewed articles published on patients presenting to accident and emergency departments between 1966 and 1999 (Benger, 2000). The authors found three relevant studies (published between 1992 and 1997). All three studies were included in the review by Roine et al. They added that using teleradiology for remote consultations reduced potentially hazardous patient transfers (Stoeger et al., 1997), increased patient preparation and reduced transportation-related adverse events (Bailes et al., 1997). They also added that transmitting images via teleradiology was more costly yet faster compared to taxi courier (Heautot et al., 1999). Finally, teleradiology was less costly than transporting the patient to a neurosurgical centre. The review’s authors appropriately concluded that there was “little evidence concerning the effectiveness of [transmitting CT scans of the head to a tertiary neurosurgical centre for immediate expert opinion]”.

Another study reviewed articles on telemedicine dating from 1996 to 2004 (Heinzelmann et al., 2005). These authors found two articles that addressed the use of teleradiology in neurosurgical consultations. One article reported that there were more favourable outcomes with real-time (synchronous) use of teleradiology compared to asynchronous use and the telephone alone (Poon et al., 2001). The other reported that teleradiology resulted in more therapeutic interventions and fewer adverse events than alternate care (i.e. telephone consultation) (Goh et al., 1997b). The review authors did not make any conclusions about the benefits of teleradiology for neurosurgical consultations. They indicated that more robust studies were needed before definitive conclusions could be drawn. Compared to other clinical areas, however, intensive care, emergency/trauma care, dermatology and cardiology have strong evidence of benefit.

Only one review focused specifically on the impact of telemedicine in the neurosciences. This review was primarily based on work done in India with some reference to studies done in other countries (Ganapathy et al., 2005). The authors demonstrated the need for teleradiology and presented original data collected over five years. The results were mostly anecdotal asserting that teleradiology consultations were valuable. Interestingly, a reduction in use of the teleradiology network was observed over the duration of the project. The authors suggest that after being in contact with specialists for a period of time, family physicians generate sufficient skills and confidence to manage most head
injuries on their own. Less than 10% of head injuries were referred for consultation or surgery in a community hospital setting. The primary shortfall of the reviews is that five out of six inappropriately reviewed teleradiology together with other applications of telemedicine. Although some authors discussed clinical applications in sub-sections, conclusions on teleradiology were integrated with other applications. As Hersh et al. (2001) correctly pointed out in their review of telemedicine, radiology unlike many other medical disciplines does not require face-to-face contact for diagnosis. Radiology stands out clinically, technically and operationally from other applications of telemedicine and must therefore be evaluated independently. In the conventional setting, the radiologist does not directly interact with patients and rarely meets with the physician with whom s/he is consulting. A second and more important shortfall in some of the reviews was that insufficient rigour was applied to defining and using robust methodologies for collecting and synthesizing data. The policy questions remain unanswered by the aforementioned reviews. The impact of teleradiology on neurosurgical consultation services in areas without specialists has not been systematically evaluated (Hailey et al., 2004). Reduction of patient transfer rates and other benefits remain to be explicitly and consistently demonstrated.
3. OBJECTIVES

Answering the policy questions requires a comprehensive assessment of legal, ethical, social, political, clinical, operational and economic issues specific to remote interpretation of images and neurosurgical consultation. Legal issues are important because healthcare standards generally dictate that specialists must be licensed to practise in the location from which consultations are initiated. Although the policy questions are specific to a province-wide teleradiology network, the current practice involves consulting specialists outside the province. There are many more questions to answer. Will licensing restrictions limit access to specialist services for patients in some areas? Is patient privacy at increased risk? How will relationships between the patient, the referring physician and the specialist change? Will the existence of teleradiology networks significantly change referral processes? Will teleradiology foster or limit collaboration locally and across provincial and national borders? Can teleradiology be linked to clinical or organizational benefits? Are economic benefits viable at the patient level or only at the provider level? The policy questions can be framed as follows:

1. What proportion of patients is incorrectly assigned using telephone consultation?
2. What impact does teleradiology have on reducing the proportion of incorrectly assigned patients?
3. Are there alternative options to teleradiology for reducing the proportion of incorrectly assigned patients?
4. How do the outcomes of incorrectly assigned patients compare to others?
5. What are the costs and burdens of inappropriately hospitalizing patients at peripheral facilities instead of transferring them to NSUs and vice-versa?
3.1 Research questions

Based on the policy questions and background information, the following research questions were developed. From the perspective of the third-party payer, when compared to telephone consultations, video-conferencing consultations or management without consultation:

1. How often do neurosurgeons change diagnoses or management plans based on transmitted images during remote neurosurgical consultations?
2. Does the level of expertise of the local staff attenuate the impact of teleradiology?
3. Are there clinical benefits directly linked to teleradiology?
4. Does teleradiology reduce the proportion of patients transferred to specialists for assessment and possible treatment?
5. Does teleradiology reduce the time it takes to provide a patient with a diagnosis or a management plan?
6. How does teleradiology affect the relationship between the patient, general physician and specialist?
7. What are the broad legal, political and ethical implications of teleradiology?
8. Are the costs associated with teleradiology offset by the savings associated with other benefits?
4. METHODOLOGY

This report includes (1) a systematic review of the evidence on the impact of teleradiology on patients requiring neurosurgical services facilities without resident neurosurgery specialists and (2) a cost-consequence analysis between teleradiology and alternate consultation methods (Canadian Agency for Drugs and Technologies in Health, 2006).

4.1 Search strategy

A comprehensive literature search was performed using MEDLINE data from 1950 and EMBASE data from 1988. The search included articles published up to and including July 2008. Searches were limited to studies done on humans. See APPENDIX A – Search Parameters for the complete list of search parameters. Reference lists of published articles were manually examined for applicable studies. All articles were stored and tracked using Endnote 6.0.2, a bibliographic database program produced by Thomson ISI ResearchSoft.

4.2 Study inclusion criteria

Content Screen

Articles were considered to be relevant if they used keywords according to the intent of the assessment. Studies had to focus on the use of teleradiology for neurosurgical consultation. For the purpose of this report specialists include neuroradiologists, neurosurgeons, neurosurgical residents and medical
personnel qualified to interpret and make diagnoses on radiographic images of the head, neck and spine.

*Types of Studies*

Randomized controlled studies, case-control studies, comparative series, observational studies, descriptive studies and economic evaluations were included. There are ethical implications for randomization studies that would potentially deny certain patients immediate access to specialists using ‘no consultation’ or ‘mail’ as comparators when an enabling technology such as the telephone is available. It was considered inappropriate to restrict the assessment to randomized controlled trials or fully-developed quantitative studies to avoid missing useful information from other types of studies.

*Population*

The population of interest consisted of human adults and children for whom radiographic images were used for neurosurgical evaluation in a healthcare facility without a neurosurgery specialist.

*Intervention*

The intervention was teleradiology – electronic transfer of radiographic images via telephone lines – for elective or urgent consultation with a neurosurgery specialist.

*Comparators*

Four types of evaluations are possible based on the type of comparator method used. Type I evaluations are those that compared outcomes when physicians used teleradiology for remote consultation with outcomes when physicians used
telephone only or telephone and mail. Type II evaluations are those that compared teleradiology with video-conferencing and telephone. Type III evaluations are those in which teleradiology outcomes were compared with outcomes when general physicians assessed patients without consulting with specialists. In any of these three types of evaluations, outcome measurements could be implied. Measurements were implied when authors did not describe a process for taking measurements for outcomes in the comparator groups. This means the comparator (telephone, mail or video-conferencing) outcomes were reported extemporaneously. Finally, in type IV evaluations, teleradiology outcomes were assessed descriptively without a comparator.

Teleradiology and telephone consultation processes were previously described in the background section. A video-conferencing system is similar to a teleradiology system with the addition of a video-link for image transmission and communication.

Outcomes

Articles included in this report addressed at least one of the following outcomes in relation to the use of teleradiology for patients in need of neurosurgical evaluation (Busse, 2002):

1. Clinical impact in terms of altered diagnoses, altered patient management decisions, and morbidity or mortality rates;

2. Organizational impact in terms of patient transfers and consultation response times;
3. Social consequences in terms of patient and physician perception of the neurosurgical diagnostic process;

4. Legal and political aspects concerning territorial autonomy and licensing;

5. Ethical issues in terms of patient privacy and access to specialists; and

6. Costs involved in purchasing, installing, operating and maintaining telecommunications equipment, training for personnel, providers’ services (including consultations), hospitalization and transportation.

Time Horizon

Although the time horizon was not restricted, short-term outcomes are expected to be most relevant.

Sample size

Restrictions were not placed on sample size as all types of studies were included.

4.3 Study exclusion criteria

Although letters and editorials were retrieved, they were excluded from the analysis along with articles describing the impact of teleradiology on education, remote neurosurgery or radiation therapy. Remote neurosurgery involves the use of telecommunications to guide surgery while radiation therapy involves the treatment of cancer.

4.4 Retrieval of records
Articles were retrieved by the author and screened by two reviewers. The author has experience in research, design and clinical evaluation of diagnostic imaging equipment but has no background in teleradiology. The abstracts and titles of records from the database searches were screened for content. An attempt was made to retrieve all articles identified as potentially relevant including those with insufficient information in their abstracts. The full text of available articles was further screened for content. Additional articles were retrieved based on manual bibliographic searches. Data from the articles that met the inclusion criteria were extracted into tables by two reviewers and critically appraised for quality. Results were discussed and discrepancies were resolved by consensus.

4.5 Quality assessment

In order to limit bias in the review, studies of interest were first classified according to methodological type then assessed for validity. Based on an assessment done by the Cochrane Collaboration, a decision was made against using published scales to determine inclusion of studies. Section 6.7.2 of the Cochrane Handbook of Systematic Reviews of interventions indicates that available quality assessments scales cannot be recommended without reservation (Higgins and Green, 2006). In section 6.11 of the Handbook, it further states that “authors should avoid the use of ‘quality scores’ and undue reliance on detailed quality assessments” as there is limited supporting empirical evidence of effectiveness. Many quality scales do not differentiate the quality of reporting from the quality of a study’s design. Furthermore, the relationship
between a study’s score and the extent to which that study is free from bias is not evident. There are no validated scales for assessing qualitative studies and the generally accepted standards for quality assessment (CASP, QUOROM Group, Cochrane Collaboration) focus primarily on assessing the quality of evidence from randomized controlled trials (Critical Appraisal Skills Programme 2002; Moher et al., 1999).

For a comparative assessment of study validity, sixteen questions were extracted from three checklists found in the literature (Appendix B – Quality assessment checklists). It was necessary to select questions as unique circumstances apply to teleradiology that are not considered in the checklists. For example, although allocation concealment prior to enrolment is possible, specialists and referring physicians can not be blinded to the mode of consultation being used. Five questions were extracted from the NHS Centre for Reviews and Dissemination guidance document for assessing the quality of case series (Kahn et al., 2001):

Q1. Was the study based on a representative sample selected from a relevant population?
Q2. Were the criteria for inclusion explicit?
Q3. Was follow-up long enough for important events to occur?
Q4. Were outcomes assessed using objective criteria or was blinding used?
Q5. If comparisons of sub-series are being made, were there sufficient descriptions of the series and the distribution of prognostic factors?

Four questions were extracted from a checklist published by Verhagen et al. to evaluate randomized controlled trials.

Q6. Was a method of randomization performed?
Q7. Were the groups similar at baseline regarding the most important prognostic indicators?

Q8. Were point estimates and measures of variability presented for the primary outcome measures?

Q9. Did the analysis include an intention-to-treat analysis?

A different checklist was used for economic evaluations (Drummond et al., 1997):

Q10. Were there comprehensive descriptions of the intervention and comparator(s)?

Q11. Were all important and relevant costs and outcomes for each option identified?

Q12. Were costs and outcomes measured accurately and consistently across comparator(s)?

Q13. Were costs and outcomes valued credibly?

Q14. Were costs and outcomes adjusted for differential timing?

Q15. Was there an incremental analysis of costs and consequences?

Q16. Were sensitivity analyses conducted to investigate uncertainty in estimates of cost or consequences?

4.6 Data extraction

The data extraction table includes the main author's last name, year the study was published, study objective(s), type of study, details about the providers (including location), number of patients enrolled in the study, patient characteristics, intervention, comparator(s), type of radiographic images (e.g. x-ray, CT MRI), method for transmitting and reviewing images, clinical evaluation and patient management protocols, relevant outcome(s), summary of impact, study limitations and general comments.
4.7 Data synthesis

Multiple options are available for data synthesis. Data from randomized controlled trials could be synthesized by calculating summary statistics through meta-analysis. The odds ratio could be calculated as the effect measure for comparing unfavourable outcomes between teleradiology and the comparators. Since heterogeneity must be minimal among studies that are included in a meta-analysis, the chi-squared test could be used to evaluate heterogeneity. In the event that there is significant heterogeneity ($I^2 >$ degrees of freedom) among studies, it may be possible to perform sub-group analyses.
5. RESULTS

5.1 Search results

Based on database searches, 3765 records were identified (Figure 5). After eliminating duplicates, records without abstracts, records in foreign languages and further screening using the keyword ‘neuro$’, 100 records were considered potentially relevant. Twenty-six records were unavailable from accessible libraries from the author’s institution. Of the unavailable articles, one article each was published in Academic Radiology, Canadian Association of Radiologists Journal, Electronic Journal of Pathology and Histology, Journal of the American Osteopathic Association, Journal of the Canadian Association of Radiologists, Journal on Information Technology in Healthcare, Medical Journal of Malaysia, Journal of Rural Health, Minimally Invasive Therapy and Allied Technologies journal, Pediatric Emergency Care, Proceedings/AMIA Annual Fall Symposium, Radiologic Technology; two each in the Journal of Circumpolar Health, Journal of Digital Imaging, Journal of Telemedicine and Telecare, Radiology Management, Studies in Health Technology & Informatics; and four in the Telemedicine Journal. None of these studies were focused on teleradiology for neurosurgical consultation. Full-text screening excluded five editorials and 51 irrelevant studies. Eighteen studies remained. Four additional articles were retrieved based on manual bibliographic searches. Of the 22 articles, eight were reviews and 14 were studies that focused on teleradiology in neurosurgical consultations. Data from the 14 studies was extracted into tables and appraised for quality. Two
studies had inadequate data. Therefore only 12 studies were included in the analysis. See Appendix C – Data extraction tables.

**Figure 5 – Search results**

```
<table>
<thead>
<tr>
<th>Literature search</th>
<th>Duplicates 190</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique records</td>
<td>Foreign Language</td>
</tr>
<tr>
<td>Abstract screen</td>
<td>Not applicable 2232</td>
</tr>
<tr>
<td>Potentially relevant</td>
<td>Not found 26</td>
</tr>
<tr>
<td>Full text screen</td>
<td>Unrelated 51</td>
</tr>
<tr>
<td>Manual search 4</td>
<td>Reviews 8</td>
</tr>
<tr>
<td>Extended search</td>
<td>Extracted data</td>
</tr>
<tr>
<td></td>
<td>Poor quality</td>
</tr>
<tr>
<td></td>
<td>Included studies</td>
</tr>
</tbody>
</table>
```

### 5.2 Study designs

The extracted body of literature was small and there was noticeable variability among the designs. The characteristics of the 12 included studies are listed by first author in alphabetical order in Table 1. Two of the studies were randomized controlled trials with type II evaluation (telephone and video-conferencing
comparators), four were observational studies with type I evaluation (telephone only or telephone and mail comparators), three were observational studies with type III evaluation (telephone outcomes were measured extemporaneously), and three were descriptive observational studies with type IV evaluation (without a comparator). Seven of the studies were prospective. Five of the studies were included in previous reviews on telemedicine.

All authors based eligibility criteria for study enrolment on patients' presenting conditions at the time of admission, including scores on the Glasgow Coma Scale (GCS), symptoms of focal neurological deficit, change in or level of consciousness, and CT or MR findings. Nonetheless, different sets of presenting conditions were included across the studies. A variety of protocols were used for assessing presenting conditions, initiating consultations, transmitting and reviewing images, making transfer decisions, managing patients, collecting data, and reporting outcomes.

In general, however, referring physicians initiated consultations to specialists via telephone. Image transmission occurred via analogue telephone lines, dedicated ISDN, internet protocol, fibre optic cable or asynchronous transfer mode. Four studies did not disclose their image transmission process. Transfer decisions were made by a neurosurgeon or neurosurgery resident in eight studies, a referring physician in one study, and by consensus in two studies. The method through which transfer decisions were made could not be extracted from one study. In two of the studies performed in Hong Kong, the referring physicians had a standard protocol for preparing and transferring patients. In the rest of the
studies, neurosurgery experts provided patient management and pre-transfer preparation advice in an *ad-hoc* manner.

**Table 1 – Study characteristics (in alphabetical order of first author’s last name)**

<table>
<thead>
<tr>
<th>Author</th>
<th>Study type</th>
<th>Evaluation type</th>
<th>TR image transmission</th>
<th>Transfer decision</th>
<th>Consultation Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baiyes (1997)</td>
<td>CCS</td>
<td>II</td>
<td>Telephone lines</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Goh (1997a)</td>
<td>CCS</td>
<td>I</td>
<td>NR</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Goh (1997b)</td>
<td>CCS</td>
<td>I</td>
<td>NR</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Heautot (1999)</td>
<td>CCS</td>
<td>I</td>
<td>ATM &amp; ISDN</td>
<td>Consensus</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Houkin (1999)</td>
<td>CCS</td>
<td>I</td>
<td>ISDN</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Kreutzer (2008)</td>
<td>CCS</td>
<td>III</td>
<td>Telephone lines</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Maass (2000)</td>
<td>CCS</td>
<td>III</td>
<td>NR</td>
<td>RP</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Poon (2001)</td>
<td>RCT</td>
<td>II</td>
<td>Dedicated ISDN</td>
<td>Specialist</td>
<td>Protocol</td>
</tr>
<tr>
<td>Stormo (2004)</td>
<td>DCS</td>
<td>IV</td>
<td>Internet Protocol</td>
<td>Specialist</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Urban (1996)</td>
<td>DCS</td>
<td>IV</td>
<td>Fibreoptic Cable and ISDN</td>
<td>NR</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>RCT</td>
<td>II</td>
<td>ISDN</td>
<td>Specialist</td>
<td>Protocol</td>
</tr>
<tr>
<td>Zulu (2007)</td>
<td>DCS</td>
<td>IV</td>
<td>NR</td>
<td>Consensus</td>
<td>Ad-hoc</td>
</tr>
</tbody>
</table>

Key: ATM=asynchronous transfer mode; CCS=comparative case series; DCS=descriptive case series; ISDN=integrated services digital network; NR=not reported; RP=referring physician; TR=teleradiology

### 5.3 Provider profiles

Two studies took place in Germany, and one each in Finland, France, Norway, South Africa and the United States (Table 2). In one study the NSU was in Japan while the referring centre was in Malaysia. Consultations were initiated by emergency physicians, general practitioners or radiologists in small community hospitals, large regional (district) general hospitals, or level 2 trauma centres (Heautot *et al.*, 1999; Urban *et al.*, 1996). Neurosurgeons or neurosurgery
residents practiced out of facilities classified as general, teaching/university hospitals or tertiary care centres. Two studies had overlapping authors and data collection dates (Goh et al., 1997a; Goh et al., 1997b). Two other studies carried out at the same NSU in Hong Kong also had overlapping authors and data collection dates (Poon et al., 2001 and Wong et al., 2006). Although all of the studies were published between 1996 and 2008, data was collected between 1995 and 2001.

Table 2 – Provider profiles

<table>
<thead>
<tr>
<th>Author</th>
<th>Country</th>
<th>Referring Centre</th>
<th>NSU</th>
<th>Data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailes</td>
<td>United States</td>
<td>SCH</td>
<td>GH</td>
<td>NR</td>
</tr>
<tr>
<td>Goh</td>
<td>Hong Kong</td>
<td>LRGH</td>
<td>TCC</td>
<td>Mar 1995 to Dec 1995</td>
</tr>
<tr>
<td>Goh</td>
<td>Hong Kong</td>
<td>LRGH</td>
<td>TCC</td>
<td>Mar 1995 to May 1996</td>
</tr>
<tr>
<td>Heautot</td>
<td>France</td>
<td>L2T</td>
<td>TH</td>
<td>18 months</td>
</tr>
<tr>
<td>Houkin</td>
<td>Malaysia, Japan</td>
<td>NR</td>
<td>TH</td>
<td>NR</td>
</tr>
<tr>
<td>Kreutzer</td>
<td>Germany</td>
<td>SCH</td>
<td>TH</td>
<td>1995-2000</td>
</tr>
<tr>
<td>Maass</td>
<td>Finland</td>
<td>LRGH</td>
<td>TH</td>
<td>1998</td>
</tr>
<tr>
<td>Poon</td>
<td>Hong Kong</td>
<td>LRGH</td>
<td>TCC</td>
<td>Oct 1998 to Jul 1999</td>
</tr>
<tr>
<td>Stormo</td>
<td>Norway</td>
<td>SCH</td>
<td>TH</td>
<td>Sept 1999 to May 2000</td>
</tr>
<tr>
<td>Urban</td>
<td>Germany</td>
<td>L2T</td>
<td>TH</td>
<td>Jan 1991 to Dec 1994</td>
</tr>
<tr>
<td>Wong</td>
<td>Hong Kong</td>
<td>LRGH</td>
<td>TCC</td>
<td>Oct 1998 to Sept 2001</td>
</tr>
<tr>
<td>Zulu</td>
<td>South Africa</td>
<td>LRGH</td>
<td>TH</td>
<td>1997-2001</td>
</tr>
</tbody>
</table>

Key: GH=General Hospital; L2T=Level 2 Trauma Care Centre; LRGH=Large Regional General Hospital; NR=not reported; SCH=Small Community Hospital; TCC=Tertiary Care Centre; TH=Teaching/university Hospital
5.4 Patient characteristics

Presenting conditions for 3224 patients were distributed as follows (Table 3): diffuse head injury/Headache/trauma (716), intracranial hemorrhage (701), stroke/cerebrovascular disease (605), miscellaneous events (348), tumor/metastases (260), subarachnoid hemorrhage (84), spinal disease/injury (65), intracerebral hematoma (37), hydrocephalus/abscess (35), subdural hematoma (33), contusion (21), extradural hematoma (10), brain infarct/fracture (7), and subdural hemorrhage (5). See Figure 6.

Miscellaneous events included infection (3), extracranial injuries (13), decreased density of white matter (1), atrophy (4), post-operative complications (1), normal CT (30), developmental anomalies (8), infection of the central nervous system (2), and unclassified (35). Poon et al. classified 81 patients with chronic subdural haematoma, subdural empyema, hydrocephalus, and brain tumours as miscellaneous. Stormo et al. classified 11 patients with hydrocephalus and chronic subdural haematoma as miscellaneous. Wong et al. included 159 patients with increased intracranial pressure or focal neurological deficit, such as brain tumor, hydrocephalus, brain abscess, and chronic subdural hematoma under miscellaneous. Unfortunately, the last three authors did not sub-classify their miscellaneous cases.
Table 3 – Patient characteristics by study

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse head injury/headache/truma</td>
<td>21</td>
<td>26</td>
<td>13</td>
<td>280</td>
<td>87</td>
<td>18</td>
<td>47</td>
<td>224</td>
<td>716</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracranial hemorrhage</td>
<td>39</td>
<td></td>
<td></td>
<td>510</td>
<td>14</td>
<td></td>
<td></td>
<td>138</td>
<td>701</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke/Cerebrovascular disease</td>
<td>8</td>
<td></td>
<td></td>
<td>5</td>
<td>48</td>
<td>159</td>
<td>29</td>
<td>29</td>
<td>327</td>
<td>605</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3</td>
<td></td>
<td></td>
<td>35</td>
<td>36</td>
<td>81</td>
<td>11</td>
<td>10</td>
<td>159</td>
<td>348</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tumor/metastases</td>
<td>14</td>
<td></td>
<td></td>
<td>39</td>
<td>5</td>
<td>80</td>
<td>7</td>
<td>Misc</td>
<td>88</td>
<td></td>
<td>Misc</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Misc</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Spinal disease/injury</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>33</td>
<td></td>
<td></td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Intracerebral hematoma</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Hydrocephalus/abscess</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misc</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Contusion</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misc</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Extradural hematoma</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Brain infarct/fracture</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Subdural hemorrhage</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Total reported</strong></td>
<td><strong>100</strong></td>
<td><strong>116</strong></td>
<td><strong>63</strong></td>
<td><strong>108</strong></td>
<td><strong>12</strong></td>
<td><strong>1024</strong></td>
<td><strong>83</strong></td>
<td><strong>327</strong></td>
<td><strong>99</strong></td>
<td><strong>393</strong></td>
<td><strong>710</strong></td>
<td><strong>189</strong></td>
<td><strong>3224</strong></td>
</tr>
</tbody>
</table>

Key: Misc=included under ‘Miscellaneous’

5.5 Outcomes

Five studies provided data on response time, eleven evaluated patient transfer rates, and four evaluated unnecessary transfer rates. Two studies reported on changes to diagnoses, four reported on changes to patient management, and five reported on clinical outcome of morbidity (four of which reported on mortality). None of the studies reported on the complete set of outcomes of interest. Six studies reported on costs.
5.6 Limitations of the studies and general comments

*Bailes et al., 1997:* The authors clearly described their methodology, accounted for all patients, reported costs and savings separately for nine hospitals, and made accurate conclusions based on the results. Limitations include reporting on only two metrics (transfer rates and costs), missing direct costs, and calculating savings based on the assumption that without teleradiology patients were “routinely transferred” to the NSU prior to implementation of the teleradiology network. As previously mentioned, the authors omitted to provide any measurements on patients in a telephone cohort. Out of a cohort of 100 patients, savings were calculated based on 33 patients being hospitalized at the referring centre. The objective of the study was to provide estimates of transportation and hospitalization savings associated with teleradiology. Although this objective may
have dominated the study design, calculating savings for teleradiology requires baseline measurements in a non-teleradiology cohort.

Goh et al., 1997a and Goh et al., 1997b: These authors compared teleradiology to telephone consultations and recorded actual measurements taken in both patient groups. The main limitations with these studies are that the authors failed to describe the image transmission process and the consultation processes were not standardized.

Heautot et al., 1999: This study had some limitations such as missing data for 11% (12/108) of patients, relatively small sample sizes and conclusions about impact were based on neurosurgeons’ estimates (and not real measurements) of activity. The telephone consultation group had only 11 patients. The objective of the study was primarily to assess the impact of image transmission methods.

Houkin et al., 2000: The small sample size of 12 limits the usefulness of this study in assessing the clinical or organizational impact of teleradiology. Comparing consultation response times between teleradiology and mail was superfluous. However, cost information for teleradiology may prove useful in combination with data from other studies. The article was a technical note describing the teleradiology link between two countries.

Kreutzer et al., 2008 and Maass et al., 2000: The authors of these studies did not describe the image transmission and review processes and did not enrol patients in a comparator group. Both studies reported on only transfer rates and costs. Kreutzer stated that “early implementation of therapy has been shown to have a significant effect on outcome in neurotrauma” and made reference to Goh et al.,
1997b. Goh reported however, that “a statistical difference [in morbidity] could not be demonstrated and mortality rates in both groups were the same”. Kreutzer reported admission rates by patient characteristics and separately listed costs associated with transferring patients from each hospital within the network. This study enrolled the largest cohort of patients and collected data over the longest period (five years). The study by Maass et al. was a descriptive analysis of a teleradiology network. This is the only study that reported treatment outcome together with transportation savings for each enrolled patient.

*Poon et al., 2001:* Although these authors categorized their study as a randomized controlled trial, several limitations were found. Patients were not adequately segmented into pathology categories and outcome at one month for 22% (58/269) of patients was missing without explanation. Statements on reduction of the number of unnecessary transfers, and discrepancy in neurological status of patients after transfer were not supported by data. The primary objective of this study was to compare the impact of both teleradiology and video-conferencing consultations to telephone consulting.

*Stormo et al., 2004:* This study had a number of limitations including the absence of a comparator and missing data. The physicians recorded response times for only 55% (48/99) of consultations. All statements about the impact of teleradiology were circumstantial. The authors suggested that when reporting on benefits, neurosurgeons may have been biased toward teleradiology as the data entry form did not allow specialists to report negative effects of teleradiology. The advantage of this study is that it reported on a mature teleradiology network.
Urban et al., 1996: Limitations of this study include reporting on transfer rates and response times and lack of data to support statements on reduction of travel distances and treatment times. Although there was indication that video-conferencing was used, the process described in the methods section was consistent with teleradiology consultation without a video-link.

Wong et al., 2006: Based on recruitment dates, it is possible that Poon et al. previously published results on a subset of the patients enrolled in this study. Unfortunately, the information provided does not give adequate proof to warrant exclusion of either study. This study fulfilled every criterion on the quality assessment checklist. Patients were randomized into three consultation groups: teleradiology, telephone and video-conferencing. Outcome measures, response time and costs were reported separately for patients with head injuries, stroke, and other characteristics. The age, sex and post-resuscitation Glasgow Coma Score (GCS) distributions among the three patient groups was similar, indicating lack of selection bias in the randomization process.

Zulu et al., 2007: Teleradiology was applicable in only 59.8% (189/316) of patients who were originally enrolled in this study. The image transmission protocol was not described and a comparator was not studied. Although a statement was made indicating that all deaths were unpreventable, the authors did not disclose the process used to determine which deaths were preventable. The authors combined data from two study phases separated by a two-year gap.
5.7 Grading the evidence

The procedure recommended by the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) Working Group guided the assessment of the overall quality of the evidence (GRADE Working Group, 2004). The procedure involves assessing the evidence for each outcome separately. Specific criteria were applied to the design of the relevant studies; the quality of the studies; directness of the patient populations, interventions and outcome measures used in the studies; modifying factors such as evidence of imprecise data; and the consistency in the estimates of effects reported across the studies.

An initial grade was assigned to each outcome based on the study designs of the relevant body of evidence. The grade was then decreased by one level when there were serious limitations to the quality of the studies, some uncertainty in directness of studies, other modifying factors (such as, evidence of imprecise data), or when there was important inconsistency in the direction and magnitude of estimates of effects. The grade was increased by one level if there was evidence of association. The overall quality of evidence was determined by the lowest quality of evidence for the critical outcomes.

Design

The initial grade was high if the body of evidence consisted only of randomized trials or low if the body of evidence consisted only of observational studies. None of the outcomes included in the current review had a body of evidence consisting only of other types of studies. Therefore, the grade of very low was not assigned. A grade of moderate was assigned if at least 50% but less than 100% of studies
were randomized trials. This is a deviation from the procedure as the GRADE Working Group does not specify criteria for assigning an initial grade to a body of evidence consisting of a mixture of studies. The initial quality grade was \textit{high} for diagnostic accuracy, \textit{moderate} for morbidity and mortality, unnecessary transfer rates and response time, and \textit{low} for the rest of the outcomes.

\textit{Quality}

A list of questions (extracted from published checklists) was used to assess the quality of each study individually. Although, it is clear from Table 4 that some studies addressed more of the questions than others, the studies were not ranked. Instead, the body of evidence was collectively assessed for each outcome and the grades were modified accordingly. Failure to randomize patients and high probability of bias in one out of two studies reduced the quality of evidence from \textit{low} to \textit{very low} for changes to diagnoses and management plans. The single RCT that was included in assessments of diagnostic accuracy, morbidity and mortality rates, patient transfer rates, unnecessary patient transfer rates, and response time had a high probability of patient overlap with another RCT. Combined with the serious limitations of the accompanying studies (Goh \textit{et al.}, 1997a, Goh \textit{et al.}, 1997b, Heautot \textit{et al.}, 1999, Houkin \textit{et al.}, 1999), the grade for morbidity and mortality rates, unnecessary patient transfer rates, and response time were reduced from \textit{moderate} to \textit{low} while the grade for patient transfer rates was reduced from \textit{low} to \textit{very low}. 

42
Consistency

Important inconsistency was found between studies that reported on morbidity at 6 months, patient transfer rates, unnecessary patient transfer rates, and response times. Consequently, the grade for morbidity at 6 months, unnecessary patient transfer rates, and response times were reduced from low to very low. Minor inconsistency was found in the results for 1 month and 6 month mortality rates.

Directness

Directness refers to the relevance of the patient population in the studies relative to the population of interest of the review. There is minor uncertainty about the directness of patient transfer rates because the protocols for consultation are different from those used in Ontario. Furthermore, three out of 4 studies that assessed patient transfer rates were done in Hong Kong. The island of Hong Kong covers just over 1000 sq. km which is approximately 1/1000th the size of Ontario. Distance between referral centers and NSUs is an important factor in making decisions to transfer critical patients. There was major uncertainty in how patient transfers were qualified as unnecessary and in how response times were calculated.

Other modifying factors

Other modifying factors were not found for any of the outcomes.
Effect

Instead of using measures such as relative risk ratios, estimates of effect were assessed in terms of the significance (p-value) of the differences in results between teleradiology and telephone consultation.

Quality of evidence for each outcome

The final grade is high for diagnostic accuracy, low for morbidity at 1 month and mortality at 1 and 6 months and very low for changes to diagnoses, patient management plans, morbidity at 6 months, patient transfer rates, unnecessary patient transfer rates and response time. The final grades can be found in the ‘Quality of evidence’ column of Table 5.

Relative importance of outcomes

The outcomes that are critical are changes to patient management, morbidity and mortality rates, and unnecessary patient transfer rate.

Overall quality of evidence

The overall quality of evidence is determined by the lowest grade for any of the critical outcomes. The grade for changes to patient management and morbidity at 6 months was very low. Therefore, the overall quality of evidence comparing teleradiology to telephone consultation is very low.
Table 4 – Answers to quality assessment questions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
</tr>
<tr>
<td>Q2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Q3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Q4</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Q5</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Q6</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Q7</td>
<td>N/A</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>Q8</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Q9</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Q10</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Q11</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Q12</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Q13</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Q14</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Q15</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Q16</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Key: N/A=not applicable; NR=not reported, RCT=randomized controlled trial

Quality assessment questions

Q1. Was the study based on a representative sample selected from a relevant population?
Q2. Were the criteria for inclusion explicit?
Q3. Was follow-up long enough for important events to occur?
Q4. Were outcomes assessed using objective criteria or was blinding used?
Q5. If comparisons of sub-series are being made, were there sufficient descriptions of the series and the distribution of prognostic factors?
Q6. Was a method of randomization performed?
Q7. Were the groups similar at baseline regarding the most important prognostic indicators?
Q8. Were point estimates and measures of variability presented for the primary outcome measures?
Q9. Did the analysis include an intention-to-treat analysis?
Q10. Were there comprehensive descriptions of the intervention and comparator(s)?
Q11. Were all important and relevant costs and outcomes for each option identified?
Q12. Were costs and outcomes measured accurately and consistently across comparator(s)?
Q13. Were costs and outcomes valued credibly?
Q14. Were costs and outcomes adjusted for differential timing?
Q15. Was there an incremental analysis of costs and consequences?
Q16. Were sensitivity analyses conducted to investigate uncertainty in estimates of cost or consequences?
### Table 5 – Quality assessment of studies comparing the impact of teleradiology to telephone on remote consultations for patients in need of urgent neurosurgical evaluation (GRADE Working Group, 2004)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Author</th>
<th>Design</th>
<th>Quality</th>
<th>Consistency in estimates of effects</th>
<th>Directness</th>
<th>Other modifying factors</th>
<th>Number of patients enrolled</th>
<th>Effect</th>
<th>Quality of Evidence*</th>
<th>Importance of Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes to diagnosis</td>
<td>Goh (1997a)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Consistent</td>
<td>Direct</td>
<td>None</td>
<td>68 &amp; 50</td>
<td>0.25</td>
<td>Very low</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td>Goh (1997b)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Consistent</td>
<td>Direct</td>
<td>None</td>
<td>35 &amp; 28</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes to patient management</td>
<td>Goh (1997a)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Consistent</td>
<td>Direct</td>
<td>None</td>
<td>66 &amp; 50</td>
<td>0.87</td>
<td>Very low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Goh (1997b)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Consistent</td>
<td>Direct</td>
<td>None</td>
<td>35 &amp; 28</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic accuracy</td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>N/A</td>
<td>Direct</td>
<td>None</td>
<td>238 &amp; 236</td>
<td>&lt;0.001</td>
<td>High</td>
<td>Important</td>
</tr>
<tr>
<td>Morbidity @ 1 month</td>
<td>Goh (1997a)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Consistent</td>
<td>Direct</td>
<td>None</td>
<td>66 &amp; 50</td>
<td>0.25</td>
<td>Low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>N/A</td>
<td>Direct</td>
<td>None</td>
<td>238 &amp; 236</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morbidity @ 6 months</td>
<td>Goh (1997b)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>35 &amp; 28</td>
<td>0.01</td>
<td>Very low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Important inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>238 &amp; 236</td>
<td>0.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality @ 1 month</td>
<td>Goh (1997a)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Minor inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>66 &amp; 50</td>
<td>0.03</td>
<td>Low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Minor inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>238 &amp; 236</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality @ 6 months</td>
<td>Goh (1997b)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Minor inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>35 &amp; 28</td>
<td>1</td>
<td>Low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Minor inconsistency</td>
<td>Direct</td>
<td>None</td>
<td>238 &amp; 236</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient Transfer Rate</td>
<td>Goh (1997a)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Minor uncertainty</td>
<td>None</td>
<td>66 &amp; 50</td>
<td>0.02</td>
<td>Very low</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td>Goh (1997b)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Minor uncertainty</td>
<td>None</td>
<td>35 &amp; 28</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heutot (1999)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Minor uncertainty</td>
<td>None</td>
<td>51 &amp; 11</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Important inconsistency</td>
<td>Minor uncertainty</td>
<td>None</td>
<td>239 &amp; 236</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unnecessary Patient Transfer Rate</td>
<td>Heutot (1999)</td>
<td>Observational study</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Major uncertainty</td>
<td>None</td>
<td>51 &amp; 11</td>
<td>0.006</td>
<td>Very low</td>
<td>Critical</td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Important inconsistency</td>
<td>Major uncertainty</td>
<td>None</td>
<td>239 &amp; 236</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response time</td>
<td>Houk (1999)</td>
<td>Technical note</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Major uncertainty</td>
<td>None</td>
<td>1024 &amp; N/A</td>
<td></td>
<td>Very low</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td>Poon (2001)</td>
<td>RCT</td>
<td>Serious limitations</td>
<td>Important inconsistency</td>
<td>Major uncertainty</td>
<td>None</td>
<td>167 &amp; 59</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wong (2006)</td>
<td>RCT</td>
<td>Minor limitations</td>
<td>Important inconsistency</td>
<td>Major uncertainty</td>
<td>None</td>
<td>239 &amp; 236</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: *The final grade for the body of evidence of each outcome. RCT=randomized controlled trial; TC=telephone consultation; TR=teleradiology consultation.
6. DATA SYNTHESIS AND ANALYSIS

Data synthesis was facilitated by systematically addressing the research questions. A descriptive approach suited the body of evidence and adequately accommodated variations in study characteristics, patient inclusion criteria (e.g. distribution of presenting conditions, age) and reported outcomes. The heterogeneity of the extracted body of data impeded attempts to perform meta-analyses. Factors unique to each study location may have attenuated or otherwise confounded the impact of teleradiology. Statistical methods like meta-analyses require that studies report on comparative populations, interventions, comparators, and outcomes. Bias was inevitable because users could not be blinded to the mode of consultation, consultation protocols were not standardized, and studies reported on selected and disparate outcomes. It would have been inappropriate to use statistical methods as meta-analyses on clinically heterogeneous and biased studies tend to have misleading conclusions (Higgins and Green, 2006).

A minority of studies reported on patients in separate sub-groups whereas most studies reported on patients collectively across age, sex, or presenting condition. Kreutzer et al. and Wong et al. divided patients into seven and three sub-groups respectively, according to their presenting condition, whereas Zulu et al. divided patients into two sub-groups based on GCS. None of the studies segmented patients by age. None of the studies assessed outcomes as a function of the ability of local expert radiologists and emergency physicians to read and report
on neurosurgical images. The impact of these nuances in study designs is demonstrated in the following analysis.

Although factors such as uncertainty, lack of reproducibility and lack of transparency are generally associated with descriptive syntheses, this review is robust and appropriate for the body of evidence under evaluation. A descriptive approach to data synthesis does not completely diminish the value of the review. A systematic method was followed in developing research questions, searching the literature, extracting data, and assessing the quality of studies. The process used was reproducible and transparent.

6.1 Clinical impact

Assessing the clinical impact of teleradiology is fairly challenging due to the nature of the intervention. Teleradiology is meant to have an impact on the consultation process, therefore typical indicators of clinical impact at the point of care such as safety and disease recurrence rates are not applicable. Clinical outcomes can only be linked to the use of teleradiology through other primary indicators. With respect to safety, teleradiology does not introduce any health hazards as it does not involve contact with the patient. Disease recurrence is applicable to therapeutic procedures and not to an ‘operational’ intervention. Teleradiology can be considered an operational intervention as it is meant to target a process rather than a specific disorder. Nonetheless, five indicators of clinical impact specific to teleradiology were found in the literature on neurosurgical consultations. These indicators were: changes to diagnoses,
changes to patient management plans, diagnostic accuracy, morbidity and mortality.

*How often do neurosurgeons change diagnoses or management plans based on transmitted images during remote neurosurgical consultations?*

Teleradiology appears to have a smaller impact on diagnoses than on patient management plans. Furthermore, the margin of difference between the impact of teleradiology and telephone consultations on patient management is 5% or less.

**Changes to patients’ diagnoses:** During remote consultation, the specialist may change the patient’s diagnosis. Although the accuracy of the remote specialist’s diagnosis can be best ascertained by comparison with a diagnosis made in-person, the specialist’s opinion drives the management plan. Specialists led transfer decision-making or patient management in 8 out of the 12 studies and had an influence in the rest of the studies. Data indicate that during remote consultation, specialists deviated from referring physicians in 5% (3/66) of patients when teleradiology was used and in 0% (0/50) of patients when the telephone was used (Goh et al., 1997a). *P-values* were not reported. In one patient in the teleradiology group, the referring physician diagnosed subarachnoid haemorrhage as viral encephalitis. In the second patient a third ventricular tumour was diagnosed as intraventricular haemorrhage, and in the third patient intraventricular blood in the third and fourth ventricles was diagnosed as a cerebellar haematoma. In their second study neurosurgeons’ remote diagnoses deviated from the referring physician’s diagnoses in 3% (1/35) of patients when teleradiology was used and in 4% (1/28) of patients when the
telephone was used (Goh et al., 1997b). In the teleradiology cases, the neurosurgeons identified traumatic subarachnoid blood missed by the referring physicians.

Changes to patient management plans: A patient’s management plan typically includes additional diagnostic tests, procedures to stabilize and treat the patient at the referring centre prior and decisions to either locally admit or transfer the patient to an NSU. The set of altered diagnoses and management plans do not completely overlap. Deviation in diagnoses did not always lead to a change in the patient’s management plan. For example, the specialist’s diagnosis had no impact on the management of the first patient in which the referring physician misdiagnosed a subarachnoid haemorrhage (Goh et al., 1997a). Nonetheless, the percentage of changes to management plans exceeded the percentage of diagnostic deviations.

In their first study, Goh et al. reported that patient management plans were changed in 21% (14/66) and 20% (10/50) of cases using teleradiology and telephone consultation, respectively. In their second study, patient management plans were changed in 29% (10/35) and 11% (3/28) of cases using teleradiology and telephone consultation, respectively. Unfortunately, the impact of altering management plans was not linked to patient outcome. Neither did the authors indicate whether the set of patients for whom diagnoses changed were mutually exclusive from the set of patients for whom management plans changed. In their case series, Heautot et al. estimated that neurosurgeons altered management plans in 20% (10/51) of patients when consulted with teleradiology. These
authors did not record data for a comparator. Similarly, Stormo et al. did not record data for a comparator but reported that 42% (42/99) of patients potentially scheduled to be transferred to an NSU had their management plan changed after teleradiology consultation. On recommendation of neurosurgeons, these patients were directed to have local pharmacological treatment or supplemental scans, were classified as moribund, or assigned to surgery at the referring centre prior to transfer. Remote consultations enabled neurosurgeons to influence patient management plans more often than they changed the diagnosis.

**Diagnostic accuracy:** An additional metric assessing clinical impact was found in the literature. Diagnostic accuracy compares the initial diagnosis made by neurosurgery specialists during remote consultation to the final diagnosis made at discharge i.e. after in-person assessment (reference standard). Wong et al. reported that the diagnostic accuracy of telephone consultation (63.8%) was significantly lower ($p<0.001$) than that of teleradiology (89.1%) and video-conferencing (87.7%). A mobile neurosurgical team made the final (in-person) diagnosis for all recruited patients. Similarly as with diagnostic deviation, the link between this metric and patient outcome was not made.

*Are there clinical benefits directly linked to teleradiology?*

None of the authors linked changes to diagnoses or management plans to survival. The likely reason is that there are a number of confounding factors between remote consultation methods and clinical outcomes. Morbidity and mortality rates are more likely correlated to other factors such as a patient’s initial neurological condition, physical condition, diagnosis protocol, transfer protocol,
treatment protocol and incidence of adverse effects (Wong et al., 2006). Consequently, without holding all these other factors constant, trying to determine the impact of consultation on morbidity and mortality of neurosurgical patients may not be practical. Even so four authors compared patient outcomes (unfavourable outcomes, morbidity, and mortality) between teleradiology and telephone consultation cohorts.

**Unfavourable outcomes:** In their randomized controlled trials, Poon et al. and Wong et al. divided patients into two groups based on whether their outcomes were favourable or unfavourable. Patients with scores lower than 4 on the Glasgow Outcome Scale (GOS) were classified as having unfavourable outcome and patients with (Glasgow Outcome Score) GOS of 4 or 5 had favourable outcome. Patients with unfavourable outcomes included those who died (GOS=1), those with minimal responsiveness (GOS=2) and those who were conscious but required daily support due to severe disability (GOS=3). Poon et al. reported unfavourable outcomes one month after admission in 69%, 62%, and 57% of patients enrolled in the teleradiology, telephone and video-conferencing consultation cohorts, respectively (Table 6). The authors did not provide the number of patients within each cohort. Wong et al. reported unfavourable outcomes in 44% (104/239), 51% (120/235), and 51% (121/236) in the same order. The difference in unfavourable outcome rates between the two studies cannot be explained by differences in the condition of patients. The overall patient distribution was similar in both studies with the exception that Poon et al. had a smaller proportion of diffuse head injuries.
Six months after admission, unfavourable outcome rates were lower. According to Wong et al. unfavourable rates were 39% (109/236), 46% (108/235) and 46% (109/236) for the teleradiology, telephone and video-conferencing consultation groups, respectively. The difference between teleradiology and telephone consultation was insignificant ($P=0.121$).

Table 6 – Proportion of patients with unfavourable clinical outcomes (including death)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>Teleradiology</td>
<td>69%</td>
<td>66% (104/239)</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>62%</td>
<td>51% (120/235)</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>57%</td>
<td>51% (121/236)</td>
</tr>
<tr>
<td>6 months</td>
<td>Teleradiology</td>
<td>NA</td>
<td>39% (93/239)</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>NA</td>
<td>46% (108/235)</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>NA</td>
<td>46% (109/236)</td>
</tr>
</tbody>
</table>

Key: *Outcomes were reported for 269 patients as information for 58 patients was unavailable at the time of publication. The distribution of patients in the three groups was not given; NA=not applicable

Morbidity: At one month follow-up, Goh et al. (1997a) also reported that 3% (2/66) of patients in the teleradiology and 8% (4/50) of patients in the telephone group suffered severe disability (Table 7). At the six-month follow-up, Goh et al. (1997b) reported in their second study that morbidity (vegetative or severe disability) rates were more than double at 11% (4/35) for the teleradiology group whereas rates for the telephone group were comparable at 18% (5/28).

According to Wong et al., morbidity (vegetative or severe disability) rates for patients in the teleradiology, telephone and video-conferencing groups were 23% (56/239), 26% (60/235), and 25% (60/236) respectively. Teleradiology was not significantly better than telephone consultations ($P=0.59$).

At six months follow-up, morbidity rates were 14% (34/239), 11% (27/235), and 13% (30/236), for the teleradiology, telephone and video-conferencing groups,
respectively. The difference between teleradiology and telephone consultation was statistically insignificant \((P=0.47)\).

**Table 7 – Morbidity rates for teleradiology, telephone and video-conferencing consultations, one month and six months after admission**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>Teleradiology</td>
<td>3% (2/66)</td>
<td>NA</td>
<td>23% (56/239)</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>8% (4/50)</td>
<td>NA</td>
<td>26% (60/235)</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>NA</td>
<td>NA</td>
<td>25% (60/236)</td>
</tr>
<tr>
<td>6 months</td>
<td>Teleradiology</td>
<td>NA</td>
<td>11% (4/35)</td>
<td>14% (34/239)</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>NA</td>
<td>18% (5/28)</td>
<td>11% (27/235)</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>NA</td>
<td>NA</td>
<td>13% (30/236)</td>
</tr>
</tbody>
</table>

Key: NA=not applicable

**Mortality:** As shown in Table 8 Goh *et al.* (1997a) reported one month mortality rates of 2% and 14% for teleradiology and telephone groups respectively. Wong *et al.* reported mortality rates for patients in the teleradiology, telephone and video-conferencing groups as 20% (48/239), 26% (60/235), and 26% (61/236), respectively. The difference between teleradiology and telephone consultation was statistically insignificant \((P=0.16)\). Zulu *et al.* reported a mortality rate of 17% (32/189) for the subset of patients for whom diagnostic scans were transferred. Thirteen percent of patients (41/316) in the entire patient enrolment group died. Goh *et al.* (1997b) reported six months mortality rates of 14% for both groups while Wong *et al.* reported rates of 25% (59/239), 34% (81/235), and 33% (79/236) for telephone, teleradiology and video-conferencing, respectively. Rates for teleradiology consultation were significantly lower \((P=0.025)\) than for telephone consultation.
Table 8 – Mortality rates for teleradiology, telephone and video-conferencing consultation, one month and six months after admission

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>Teleradiology</td>
<td>2% (1/66)</td>
<td>NA</td>
<td>20% (48/239)</td>
<td>17% (32/189)*</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>14% (7/50)</td>
<td>NA</td>
<td>26% (60/235)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>NA</td>
<td>14% (4/28)</td>
<td>26% (61/236)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>Teleradiology</td>
<td>NA</td>
<td>14% (5/35)</td>
<td>25% (59/239)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Telephone</td>
<td>NA</td>
<td>14% (4/28)</td>
<td>34% (81/235)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Video-conferencing</td>
<td>NA</td>
<td>NA</td>
<td>33% (79/236)</td>
<td>NA</td>
</tr>
</tbody>
</table>

Key:* Includes only patients with CT scans (189). Manually extracted from figure 1 in the article. Zulu et al. reported mortality rates immediately and not at 1 month. Mortality rate was lower for entire group, including patients without CT scans, 13% (41/316). NA=not applicable.

Overall, the results on morbidity and mortality are mixed. It is difficult to determine whether differences in morbidity and mortality rates across studies were due to the use of teleradiology or due to differences in triage protocols and increasing cautious attitudes of physicians over the time-span of the studies.

Teleradiology can be linked to morbidity and mortality only through one or more primary indicators such as a patient’s initial (presenting) neurological condition, diagnostic accuracy of the medical team, diagnosis protocol and response time, pre-transfer and monitoring protocols, treatment protocols, incidence of adverse effects and access to adequately skilled personnel (Wong et al., 2006). For example, Zulu et al. observed that 67% (28/42) of patients with GCS ≤ 8 died while only 5% (13/274) with GCS > 8 died. Irrespective of the method of consultation, GCS predictably appears to be a confounder.
6.2 Organizational impact

Teleradiology is expected to have more impact on facility operations than on clinical outcomes. The proportion of patients transferred after consultation is the most commonly reported outcome measure of teleradiology.

*Does teleradiology reduce the proportion of patients transferred to specialists for assessment and treatment?*

Teleradiology was found to decrease the patient transfer rate but the impact is not as significant as is generally acknowledged. One of the studies most often referenced in the literature to support the use of teleradiology is the first by Goh *et al.* (1997a) that states that teleradiology reduces transfer rates over telephone consultation by 21% (from 100% to 79%). Other studies by Wong *et al.*, Goh *et al.*, 1997b and Heautot *et al.*, 1999, report smaller differences between teleradiology and telephone consultations, with teleradiology reducing transfer rates by 7% (from 36% to 29%), 11% (from 100% to 89% and 14% (from 91% to 67%), respectively. The study by Wong *et al.* is the most recent and uses a baseline (of 36%) for telephone consultation that is significantly different from the other studies. Patients were randomized into consultation arms and a standard protocol for telephone consultations was used. Overall, absolute patient transfer rates ranged from 19% to 89% with teleradiology and from 36% to 100% with telephone consultation (Table 9).

The size or type of the referring centres can not explain the wide range in teleradiology transfer rates between studies nor can it explain the difference between teleradiology and telephone transfer rates. Four out of five of the studies
with the lowest transfer rates were reported from referring centres that were classified as large regional general hospitals. Coincidentally, three of the four studies with the highest transfer rates also had large regional general hospitals or a level 2 trauma centre as referring centres.

It is surprising that telephone transfer rates as high as 100% were reported from referring centres that were district regional hospital (Goh et al. 1997a; Goh et al. 1997b) and a level 2 trauma centre with intensive care and neurology departments (Heautot et al., 1999). Another study estimated (but did not measure) that 100% of patients were transferred without consultation prior to the installation of a teleradiology network (Kreutzer et al., 2008). It is even more intriguing that Wong et al. reported from the same referring centres as Goh et al., yet measured a transfer rate of 36% for telephone consultations. The discernable difference between these latter studies was that Wong et al. provided a standard protocol for telephone consultations. Transfer decisions were made on an ad-hoc basis for 10 out of 12 studies, therefore existence of a standing protocol can not completely explain all the differences in patient transfer rates.

**Limits on patient transfer rates:** The extent by which teleradiology can affect patient transfer rate is limited (Figure 7). The baseline transfer rate is set by telephone consultation while the lower limit is set by the proportion of patients exempt from hospitalization at a referring centre. Patients’ exemption is dictated by the healthcare network’s emergency care protocols and the capacity of the referring centre to provide basic neurosurgical services.
Table 9 – Proportion of patients transferred from referring hospitals to NSUs

<table>
<thead>
<tr>
<th>Author</th>
<th>Teleradiology</th>
<th>Telephone</th>
<th>Video</th>
<th>No consultation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailes (1997)</td>
<td>67% (67/100)</td>
<td>NA</td>
<td>NA</td>
<td>NR</td>
</tr>
<tr>
<td>Goh (1997a)</td>
<td>79% (52/66)</td>
<td>100% (50/50)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Goh (1997b)</td>
<td>89% (31/35)</td>
<td>100% (28/28)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Heautot (1999)</td>
<td>67% (34/51)</td>
<td>91% (10/11)</td>
<td>63%</td>
<td>NA</td>
</tr>
<tr>
<td>Houkin (1999)</td>
<td>NR</td>
<td>NR</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Kreutzer (2008)</td>
<td>32% (330/1024)</td>
<td>NA</td>
<td>NA</td>
<td>100%*</td>
</tr>
<tr>
<td>Maass (2000)</td>
<td>19% (15/83)</td>
<td>NA</td>
<td>NA</td>
<td>NR</td>
</tr>
<tr>
<td>Poon (2001)</td>
<td>38% (63/167)</td>
<td>NR</td>
<td>NR</td>
<td>NA</td>
</tr>
<tr>
<td>Stormo (2004)</td>
<td>46% (45/99)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Urban (1996)</td>
<td>41% (161/393)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>29% (68/239)</td>
<td>36% (83/235)</td>
<td>36% (84/236)</td>
<td>NA</td>
</tr>
<tr>
<td>Zulu (2007)</td>
<td>27% (51/189)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Key: *Measurement was implied, NA=not applicable (authors did not study this comparator), NR=not reported (authors studied this comparator but did not report a measurement)

Figure 7 – Limits on impact of teleradiology on patient transfer rates

- Patients that require transfer as dictated by protocol
- Potential impact of teleradiology
- Patients that are not transferred

Baseline transfer rate established by telephone consultation

Patient transfer rate

Threshold on teleradiology patient transfer rates

Key: RC=referring centre; 0% patient transfer rate means all patients are treated at the peripheral hospital; 100% patient transfer rate means all patients are transferred to NSU for treatment.
Some patients will present with conditions that the health system’s protocols may indicate are unlikely to be correctly diagnosed and managed remotely. These patients have to be transferred to an NSU regardless of their imaging results. For example, Goh et al. (1997b) state that the prevailing facility policy “dictates” that all patients with head injuries must be transferred for observation regardless of the outcome of their initial CT scans. The protocol was followed to rule out “delayed or evolving lesions”. In their study, 44% of transferred patients (26/59) had CT scans that showed no abnormalities. Half of these patients were subsequently diagnosed with diffuse head injury and 10 required intracranial pressure (ICP) management.

**Unnecessary patient transfers:** Unnecessary transfers are those cases that are sent to a neurosurgery unit even though they do not require care from a neurosurgery specialist. These patients are often returned to the referring centre, without advanced care. Heautot et al. measured 4% unnecessary transfers in a cohort of 51 teleradiology consultations compared with 36% in 11 telephone consultations (Table 10). Unnecessary transfers were calculated by asking the neurosurgeons in how many cases their decisions would have been different if they had seen images (telephone consulting group) or not seen images (teleradiology group). Wong et al. reported unnecessary transfer rates of 5% (11/239), 4% (9/235) and 3% (7/236) for teleradiology, telephone and video-conferencing respectively. The difference between teleradiology and telephone consultation was statistically insignificant ($P=0.68$). An independent neurosurgery
specialist decided whether transfers were necessary. The validity of using an independent specialist as a reference was not discussed.

Table 10 – Proportion of patients unnecessarily transferred from referral hospitals

<table>
<thead>
<tr>
<th>Author</th>
<th>Teleradiology</th>
<th>Telephone</th>
<th>Video</th>
<th>No consultation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heautot (1999)</td>
<td>4% (2/51)</td>
<td>36% (4/11)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>5% (11/239)</td>
<td>4% (9/235)</td>
<td>3% (7/236)</td>
<td>NA</td>
</tr>
</tbody>
</table>

Key: NA=not applicable i.e. authors did not study the comparator

**Does teleradiology reduce the time it takes to provide a patient with a diagnosis or a management plan?**

The response time is the interval between the time a consultation is requested and the time a diagnosis is made or a management plan is developed. Response times for teleradiology and video-conferencing varied widely in the literature and appear to be highly dependent on equipment set-up times. The availability of neurosurgery specialists is obviously a gating factor, along with the mode of consultation. For example, in the study by Houkin *et al.*, the comparison involved sending images to the specialist via mail. Response time was driven by the length of time it took to transfer the images to the NSU. It appears that all cases evaluated in this study were elective and not urgent. Five patients had tumours/metastases, five had stroke/cerebrovascular disease, and five had spinal disorders. The authors reported a decrease in response time from 4 days to 18 minutes when teleradiology was used in place of mail to transfer images (Table 11). It is surprising that Houkin recorded response time in the comparator group as the time taken to mail images rather than the time taken to diagnose by telephone. The latter would have been a better measure of response time. Poon
et al. discovered that teleradiology responses were on average slower (49.2 minutes) than telephone consultations (1.8 minutes) but not video-conferencing (65.4 minutes). It must be noted that these response times included 36 and 55 minutes to set up equipment for teleradiology and video-conferencing, respectively. Wong et al. reported average response times of 60.6 ± 108, 42 ± 114 and 78 ± 150 minutes for teleradiology, telephone and video-conferencing respectively. The authors did not state whether these times included equipment set-up. Nonetheless, the telephone response times are significantly higher when compared with values reported by Poon et al. Stormo et al. reported median response times of 180 minutes in cases of emergency and 1 day for non-emergent teleradiology consultations while Urban et al. reported an average of 15 minutes for emergency cases. Finally, Heautot et al. reported average response times of 11.7±10.9 for teleradiology. It would not be prudent to quantitatively synthesize response time data as it is not clear whether all authors included set-up times in their measurements.

Table 11 – Average response times (minutes)

<table>
<thead>
<tr>
<th>Author</th>
<th>Teleradiology</th>
<th>Telephone</th>
<th>Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heautot (1999)</td>
<td>11.7±10.9</td>
<td>NR</td>
<td>NA</td>
</tr>
<tr>
<td>Houkin (1999)</td>
<td>18</td>
<td>5760</td>
<td>NA</td>
</tr>
<tr>
<td>Poon* (2001)</td>
<td>49.2</td>
<td>1.8</td>
<td>65.4</td>
</tr>
<tr>
<td>Stormo (2004)</td>
<td>180 - 1440</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Urban (1996)</td>
<td>15</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>60.6±108</td>
<td>42±114</td>
<td>78±150</td>
</tr>
</tbody>
</table>

Key: *Includes set time of 36 minutes for teleradiology equipment and 55 minutes for video-conferencing equipment, NA=not applicable
Based on the above assessment, additional data is required to make conclusions about response times.

6.3 Social consequences

Two studies used questionnaires to evaluate the impact of teleradiology on relationships between referring physicians and neurosurgery specialists.

Although physicians were not directly asked how the method of consultation affected their relationships, conclusions were deduced based on patterns of use. *How does teleradiology affect the relationship between the patient, general physician and specialist?*

None of the studies adequately described a process for assessing the impact of teleradiology on relationships. Goh *et al.* (1997a) stated that one of the benefits of teleradiology was that neurosurgeons would be more confident in making decisions when preventing patient transfers. Goh *et al.* (1997b) stated that it was reasonable to conclude that “teleradiology improves information acquisition, thus resulting in a clearer clinical impression of the patient as a whole”. Unfortunately the published evidence is still inadequate to substantiate the claim that teleradiology helps raise the neurosurgeon’s level of confidence.

*Level of interaction between physicians*

According to Heautot *et al.*, all decisions were made by consensus in the telephone and teleradiology groups. However, details on the process of interaction were missing. Conversely, neurosurgeons evaluated 26.5% (12/46) of video-conferencing sessions without interacting with the referring physicians and
evaluated another 26.5% (12/46) alone after having an initial conversation with the referring physicians via video-link. Only 47% (22/46) of cases were fully interactive. Most discussions took place between emergency department physicians at the referring centre and neurosurgeons at the neurosurgical unit. Heautot et al. also reported that 6% (3/51) of teleradiology consultations were optional calls for advice compared to 21% (7/34) in the video-conferencing group. The proportion of optional calls in the telephone group was not reported; therefore it is impossible to determine whether teleradiology improved collaboration between referring physicians and neurosurgeons. Incidentally, only 11 cases were enrolled in the telephone group. Stormo et al. reported that referring physicians used teleradiology to ask for advice on non-surgical treatment options for moribund patients and other patients admitted locally. The authors made reference to their experience as a measure that such advice was beneficial to physicians in community hospitals and increased the quality of care for patients. They did not report on data collected from physicians participating in the study.

Poon et al. indicated that the experience of the referring physician will drive the accuracy of information exchanged over the telephone; however, the authors did not provide details on the training and experience of the referring physicians. Similarly, Goh, Houkin, Kreutzer, Maass, Stormo, Urban, and Wong did not provide these details. Bailes reported that 66 consultations were initiated by the emergency medicine department, 15 by internal medicine, 9 by radiology, 6 by
surgery and 4 by neurosurgery. Zulu et al. reported that patients were enrolled from the surgical unit of the referring centre.

6.4 Legal, political and ethical aspects

*What are the broad legal, political and ethical implications of teleradiology?*

None of the studies assessed ethical issues associated with the use of teleradiology. Unlike in telephone consultations, patient privacy may be at risk if images are not adequately encrypted during teleradiology transmission. Bailes et al. pointed out in their discussion that “from a medicolegal perspective”, prior to teleradiology it was preferable for neurosurgeons to take a conservative approach and request patient transfers when verbal descriptions were inadequate. Unfortunately, the study methodology did not include a tool for collecting such information from physicians and the authors did not provide data to support these conclusions. The authors also stated that “using telemedicine was more medically appropriate” yet they did not study a comparator group.

In one review, authors indicated that there are ethical issues associated with using inappropriate comparators such as *no consultation* or *mail* when potentially better technologically-advanced options (such as the telephone) are available (Heinzelmann et al., 2005).

6.5 Summary of costs

The available data on resource use and costs was insufficient to support a cost-effectiveness analysis. Only six studies reported costs involved in neurosurgical
consultations and none of these studies gave a comprehensive account. Cost data was presented in a number of different ways. Some studies provided a list of variable and fixed costs. Others presented savings gained from locally hospitalizing patients at referring centres rather than at NSUs or from replacing a more expensive transportation mode with a less expensive one. Only a rudimentary cost-consequence analysis is possible with this data set. A cost-consequence analysis involves compiling an itemized list of costs and describing the conditions under which the costs were calculated.

**Direct costs:** Only direct costs were reported in the studies. Indirect costs such as those related to loss of labour, long-term disability costs, and family member expenses would be more applicable to an analysis done from a societal perspective. Variable costs are those incurred per patient or case (Table 12). These costs include image transmission charges, hospital reporting charges and teleradiology consultation fees. Transportation costs are excluded. Heautot et al. reported transmission charges of 7.5 pence (19 cents) per 30 – 90 seconds. Transmission charges were based on the bandwidth of the system and the time of day that the system was in use. At the high end of the rate scale, the transmission charge was calculated at 15 pence (38 cents) per minute (Currency conversion date: April 1, 1999). Houkin et al. reported a higher charge of ¥190 ($2.33) per minute for transmission between Malaysia and Japan (Currency conversion date: January 1, 1999). Teleradiology consultations lasted an average of 18 minutes (including 3 minutes for image transmission and 15 minutes for discussion) costing ¥3420 ($47.58). Transmission costs were directly
proportional to the duration of consultation. Currency conversion rates were calculated for the month or quarter in which the study was published (The Currency Site website, 2009).

Other authors reported an aggregate cost for teleradiology. Maass et al. reported that the NSU charged each RC a teleradiology consultation fee of €156 per patient including a €56 ($98) hospital reporting charge and €100 ($175) for local personnel time, network rental costs and maintenance (Currency conversion date: January 1, 2000). Wong et al. reported an average combined cost of HKD14455 ($2060) per patient (Currency conversion date: September 1, 2006). This single cost included variable and fixed costs: diagnostic imaging, teleradiology consultation, hospitalization, physiotherapy procedures, operating room time and extended care.

Fixed costs for a teleradiology network include monthly telecommunication fees and one-time equipment purchase and installation costs. The cost of purchasing air or ground ambulances is excluded. Heautot et al. reported a monthly system rental fee of £20 ($50), Maass et al. reported that a CCD camera (digitizer) was purchased for €25,000 ($43,724) while Kreutzer et al. reported purchasing teleradiology systems at a price of €12,000 ($17,783) per system.
Table 12 – Teleradiology costs ($, Canadian dollars)

<table>
<thead>
<tr>
<th>Author</th>
<th>Image transmission (per minute)</th>
<th>Aggregate (per patient)</th>
<th>Transmission rental (per month)</th>
<th>Equipment (per system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heautot (1999)</td>
<td>$0.38</td>
<td>NR</td>
<td>$50</td>
<td>NR</td>
</tr>
<tr>
<td>Houkin* (1999)</td>
<td>$2</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Maass (2000)</td>
<td>NR</td>
<td>$273</td>
<td>NR</td>
<td>$43,724</td>
</tr>
<tr>
<td>Wong (2006)</td>
<td>NR</td>
<td>$2,060</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Kreutzer (2008)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>$17,783</td>
</tr>
</tbody>
</table>

Key: *Houkin et al. reported that transmission of radiographic images lasted an average of 3 minutes per patient; **Mass et al. combined costs for network rental costs, reporting time, maintenance and personnel time; Wong et al. combined costs for diagnostic imaging, teleradiology consultation, hospitalization, physiotherapy procedures, operating room time and extended care; NR=not reported.

More important than a list of costs is the overall impact of savings. The next research question addressed savings.

*Are teleradiology costs offset by the savings associated with reduction in patient transfers?*

Overall, facilities using teleradiology generated financial savings by (1) avoiding transportation costs and reducing hospitalization costs, and (2) by using ground rather than air (more expensive) ambulance. Transportation costs were avoided by reducing patient transfer rates and hospitalizing more patients locally. No cases were reported in which teleradiology changed a patient’s mode of transportation from ground to air.

*Savings due to reduction of patient transfer rates:* In their study conducted in Western Pennsylvania, Bailes et al. reported that by hospitalizing 33 out of 100 patients locally, they avoided US$227,454 ($313,159) in air transportation costs.
and US$90,750 ($124,945) in hospitalization costs.\(^{c,d}\) (Table 13). Kreuter et al. locally hospitalized 694 out of a cohort of 1024 patients. The authors reported that patients were transferred at three different rates: €36.94 + 1.8/km when patients were mild or moderately ill and unaccompanied by a physician; €508.90 when patients were intubated and ventilated but stable and accompanied by a general physician; or €559.90 when patients were potentially unstable and accompanied by an intensive care unit physician. Kreuter et al. reported total avoided transportation costs of €151,977 ($225,213), €348,088 ($515,828) and €382,972 ($567,522) respectively.\(^e\) At a transfer rate of 19%, Maass et al. generated savings (from avoided transportation costs alone) of €13,600 ($23,786) in a cohort of 83 patients.

### Table 13 – Total air transportation and hospitalization costs avoided by locally hospitalizing patients in teleradiology cohorts (S, Canadian dollars)

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Patients</th>
<th>Transfer rate</th>
<th>Patients locally hospitalized</th>
<th>Air transportation costs avoided</th>
<th>Hospitalization costs avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailes (1997)</td>
<td>100</td>
<td>67%</td>
<td>33</td>
<td>$313,159</td>
<td>$124,945</td>
</tr>
<tr>
<td>Kreutzer (2008)</td>
<td>1024</td>
<td>32%</td>
<td>694</td>
<td>$515,828</td>
<td>NR</td>
</tr>
<tr>
<td>Maass (2000)</td>
<td>83</td>
<td>19%</td>
<td>67</td>
<td>$23,786</td>
<td>NR</td>
</tr>
</tbody>
</table>

**Ground versus air transportation:** Savings can be gained by switching from air to ground transportation only in circumstances where a mixed mode of transportation is available. Bailes et al. reported ground transportation costs were

\(^{c}\) Costs were converted to Canadian currency using bank rates at the beginning of the month or quarter in which the study was published.

\(^{d}\) With ground ambulance the costs avoided would be much lower at $33,948 ($1211 per patient). Average ground transportation per patient cost 82% less than air transportation. Hospitalization savings were calculated based on rates of US$1250 per patient per day at the RC versus US$4000 per patient per day at the NSU.

\(^{e}\) The authors only included seven affiliated hospitals when calculating avoided costs. Ten patients were excluded.
82% less than air transportation (Table 14). Additional costs of US$184,434 ($253,929) were avoided by transporting 38 out of 67 patients by ground (US$41,280) rather than by air (US$225,714) ambulance. On average, transportation by ground ambulance cost US$1086 ($1496) per patient while air ambulance cost US$5940 ($8178). Maass et al. reported that ground transportation at €225 ($394) per patient was 96% cheaper than air ambulance at €5700 ($9969) per patient. It cost €1.8/km to €3.3/km to transport a patient by ground and €36/km by air. Kreutzer et al., reported that it costs an average of €421 ($624) to transport one patient by ground ambulance from RCs located at an average of 88km from the NSU. These authors studied hospitals that used only ground transportation.

![Table 14 – Difference in air transportation and ground transportation costs per patient ($, Canadian dollars)](image)

<table>
<thead>
<tr>
<th>Author</th>
<th>Ground transportation costs</th>
<th>Air transportation costs</th>
<th>% Difference in costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailes (1997)</td>
<td>$1,496</td>
<td>$8,178</td>
<td>82%</td>
</tr>
<tr>
<td>Kreutzer (2006)</td>
<td>$624</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Maass (2000)</td>
<td>$394</td>
<td>$9,969</td>
<td>96%</td>
</tr>
</tbody>
</table>

### 6.6 Contextualization of costs to Ontario

Certain direct costs are not applicable in the context of the Ontario healthcare system. An external digitizer is not relevant to the Ontario healthcare scenario as

---

1 Using data provided for each RC, ground transportation ranged from US$884 to US$1796 per patient and air transportation from US$2618 to US$9890 per patient.
2 Bailes reported that it cost US$41,280 to transfer 38 patients by ground transportation and estimated that it would have cost US$225,714 by air.
3 The seventeen RCs were located between 31km and 191km from the NSU.
external digitization is not required for transmitting standard CT or MRI images.

Network rental fees, maintenance and consultation fees may be allocated differently than reported in the studies and amortization may affect allocation of costs. Capital equipment costs may be amortized over 5 years, rather than 10 years. As none of the studies was done in Canada very little can be gleaned from the absolute costs reported.

6.7 Contextualization of savings to Ontario

Transportation savings varied based on the RC, distance between the RC and the NSU, transportation mode (air versus ground), and additional monitoring requirements during transfer. The transportation mode was selected based on the condition of the patient prior to transfer and the distance of the RC from the NSU. Most studies included a mix of RC distances, patient conditions and transportation mode. None of the studies provided details on the components of transportation costs. These costs may have included ambulance maintenance fees, fuel costs, and personnel time. Hospitalization costs also varied according to the RC and NSU. These costs included daily charges for occupying a bed in an in-patient ward or in the intensive care unit.

Savings can be accurately calculated only when the reduction in patient transfers is appropriately determined. Unfortunately, the three studies that reported on savings did not measure transfer rates in real comparators; therefore the reported reduction in transfer rates may have been overestimated. Without showing measurements or describing a method for acquiring measurements, two
of the studies estimated 100% transfer rates for telephone consultation. The three studies reported that teleradiology resulted in transfer rates of 67% (Bailes et al.), and reduced rates from 100% to 32% (Kreutzer et al.), and from 100% to 19% (Maass et al.) compared to telephone consultation. Bailes indicated that patients for whom neurosurgical consultations were made required transfer “routinely”, implying a transfer rate close to 100%. Incidentally, the current transfer rate in Ontario is 49% for patients who generated telephone consultation (CritiCall data, 2009). Starting from this threshold, the expected benefit of teleradiology is not nearly as dramatic compared with starting from 100%. In fact, the teleradiology system reported on by Bailes would be of no benefit to the Ontario situation as the patient transfer rate, reported for teleradiology, is higher than the existing rates with telephone consultation.
7. DISCUSSION

Given the variation in study objectives, patient prognoses, and heterogeneity of study designs, it was not possible to report on summary statistics. The available evidence is inadequate to either support or oppose the use of teleradiology for neurosurgical consultations within Ontario. There is sufficient uncertainty in the data to warrant further analysis.

In light of the findings of this review and the diffusion pressures surrounding the use of teleradiology, decision-makers should consider getting actively involved in managing the introduction of the technology into the neurosurgical consultation process. In particular, decision-makers must acknowledge that (1) the impact of teleradiology on patient transfer rates may have been overestimated in some studies, (2) teleradiology has not been directly linked to primary clinical outcomes such as morbidity and mortality, and (3) teleradiology is relevant for only a proportion of patients seeking neurosurgical assessments. There are limits to the extent to which teleradiology can impact clinical and operational outcomes in Ontario.

7.1 Limits to impact on patient transfer rates

There is a limit to the magnitude by which teleradiology can reduce patient transfer rates within Ontario. The baseline patient transfer rate has been established by the current telephone consultation process. A lower threshold exists because there are patients for whom the system protocol demands transfer. In Ontario, the neurosurgery expert panel has recommended that
irrespective of local availability of radiographic images, some patients should be treated in facilities that “have a critical mass of highly specialized health care providers, advanced equipment, and a large capital expenditure to ensure safe, high quality care” (Rutka et al., 2007). Of the 14 NSUs that exist in Ontario, at least four cannot provide advanced care. As there are no plans for developing advanced care capacity at peripheral hospitals in Ontario, the lower threshold for patient transfer rates will remain.

An estimate of the lower threshold for patient transfer rates can be extracted from the literature. Evidence from the reviewed studies indicates that the absolute difference in transfer rates between telephone consultation and teleradiology is in the range of 7% to 21%. Therefore, starting with the current telephone consultation transfer rates of 49% and the largest quoted absolute difference of 21%, the patient transfer rate using teleradiology is expected to bottom out at approximately 28%.

### 7.2 Limits to impact on clinical outcomes

An adequate assessment of the incremental impact of teleradiology consultation on morbidity and mortality requires a large number of patients. Before embarking on a study that includes morbidity and mortality in its list of outcomes, researchers must be clear about their objectives and ensure that their study design can accommodate the requirements. Intermediate outcomes such as occurrence of adverse events may be better metrics for evaluating the impact of remote consultation methods.
7.3 Implementation issues

Most sophisticated teleradiology networks are prone to compatibility and maintenance issues and are expensive because they require hardware in every connected peripheral (non-specialist) facility (Houkin et al., 1999; Stormo et al., 2004). Although compatibility issues are not anticipated in an Ontario-wide teleradiology system, the operating and maintenance costs may be significant. Political implications were not discussed in the literature and, along with ethical issues, are not readily evident in the Ontario scenario. Change in access to neurosurgeons was not discussed. Teleradiology may only impact the speed with which a patient receives attention from a specialist. Patient privacy is primarily also unaffected as images are transmitted only to specialists involved in assessing patients.

Finally, evidence on social consequences was poorly reported and the information is not generalizable to the Ontario healthcare system.

7.4 Alternatives to teleradiology

Two alternate solutions to teleradiology were found in the literature. First, results suggest that improving telephone consultations could have a significant impact on the proportion of patients transferred to NSUs (Wong et al., 2006; Goh et al., 1997a). Wong et al. showed that when a protocol was explicitly established for telephone consultations, the impact of teleradiology was insignificant with respect to diagnostic accuracy, unnecessary patient transfer rates, and morbidity. It is conceivable that a well-designed telephone consultation process involving skilled
referring physicians and including a standard protocol requesting consultations and for preparing patients prior to transfer may minimize the need for transmitting images during remote consultations. Incidentally, Goh et al. 1997a suggests completion of a standard checklist at the referring hospital can have a significant impact on improving the safety of transfers, thereby reducing adverse effects. A second option involves the use of a mobile (flying) neurosurgical team (Goh et al., 1997a and 1997b). This option was used to treat four patients out of a cohort of 35 patients assessed via teleradiology. All four patients had surgery. Two of the patients were discharged within two weeks while two died. Of the latter two, one had severe diffuse head injury with signs of brain stem ischemia and one had acute subdural hematoma with gross midline shift and effacement of basal cisterns. The cost and practicalities (e.g. small number of qualified neurosurgery specialists) associated with transporting highly skilled individuals in air ambulances make this option unrealistic in Ontario. Furthermore, small referring centres may not be able to offer adequate post-operative care to some patients.

7.5 Limitations of the review

The application of this review is limited by the quality and quantity of published studies on neurosurgical consultations. The review encompasses emergent and non-emergent neurosurgical consultations and includes data from facilities in countries where standard consultation protocols are either non-existent or differ from those used in Ontario.
8. POLICY RECOMMENDATIONS

The most important question from this review is whether it is reasonable to take on the operational challenges and costs of implementing a teleradiology network to avoid inappropriately assigning a small number of patients to hospitalization at referring centres or NSUs. Inappropriate assignments include patients that are transferred to NSUs even though they do not need advanced care and those who are hospitalized at referring centres even though they require advanced treatment at NSUs.

8.1 Further work: a study proposal for evaluation of effectiveness

This proposal outlines a protocol for evaluating the impact of teleradiology compared with telephone consultation in patients needing neurosurgical assessments in peripheral facilities located in the province of Ontario.

Objectives: The first phase will focus on optimizing and standardizing telephone consultation protocols, and training referring physicians to provide basic pre-transfer treatment protocols and effectively communicate radiographic results. These optimized protocols are important and should therefore be completed irrespective of the introduction of teleradiology. The second phase will focus on comparing patient transfer rates, diagnostic accuracy, clinical outcomes and
costs associated with assessing patients using the telephone versus teleradiology.

*Methodology:* The study is a multi-phased, prospective randomized controlled trial. Patients will be randomly assigned into an intervention group and a comparator group using a binary random number generator. Equal number of patients will be assigned to each group. Patients will be randomized at selected peripheral facilities.

*Patient population:* Patients with head-related injuries or conditions for whom remote consultations are requested will be enrolled into the study irrespective of their age.

*Intervention:* Teleradiology consultation

*Comparator:* Improved telephone consultation

*Outcomes:* Metrics of effectiveness will include (1) patient transfer rates, (2) accuracy of patient hospitalization assignments, (3) diagnostic accuracy, (4) length of stay, and (5) morbidity and mortality rates.

*Time horizon:* A data collection period of 12 months will be sufficient to provide preliminary information on the outcomes of interest.

*Phase I*

A panel of neurosurgeons and referring physicians will be assembled and asked to draw up guidelines to improve telephone consultations. The guidelines will involve instructions for quickly separating moribund cases (that will likely not
benefit from transfer to an NSU) from other cases (who may need immediate attention from neurosurgical experts). They will also include instructions for optimal medical care during transportation and recommendations for ground transportation over air transportation whenever safe. A collective process may be appropriate for this task since neurosurgeons and referring physicians may approach consultations differently. Referring physicians should represent the spectrum of practice patterns. This means physicians with high referral rates should be included along with physicians with low referral rates. At the end of the first phase, new consultation protocols will be disseminated to all NSUs.

**Phase IIa**

In the second phase, patients will be randomly enrolled at peripheral centres into one of two groups: a teleradiology group and a telephone group. Data will be collected at one NSU that uses the improved telephone consultation protocols and is connected to its referring centres via teleradiology and another NSU that uses the improved telephone consultation protocols only. At the end of phase IIa, patient transfer rates will be compared across the two patient groups and retrospectively with the rates previously recorded for the two NSUs. Diagnostic accuracy will be calculated separately in each group by comparing the diagnosis made by the remote specialists and the final diagnosis at discharge. Sub-group analyses will be performed to evaluate morbidity and mortality by patients’ presenting conditions.
**Phase IIb**

Using a third-party payer perspective, only direct costs will be assessed. A costing chart will be populated according to specific assumptions listed below.

Consultation costs will be divided into two categories: costs incurred at the referring centre alone (*initial assessment costs*), and those that are consultation-specific (telephone/teleradiology *consultation costs*). Some of these costs are variable and some are fixed (Table 14). The following assumptions were used when generating the costing chart:

1. All facilities have diagnostic imaging equipment and digitizing equipment.
2. Purchase and maintenance of ambulances are outside the scope of the analysis. Only variable costs related to patient transfer and hospitalization are included.
3. Standard-of-care (i.e. current pattern of care) is telephone consultation (without image transfer).
4. Non-surgical treatment and stabilization procedures are used only when requested during consultation. Local physicians who do not consult with specialists only decide where patients are going to be treated.

Using these assumptions, variable costs per patient for telephone consultation are shown in Table 15:

\[
C_{V_{\text{Telephone}}} = \text{Initial assessment costs} + \text{Telephone consultation costs}
\]

\[
\text{Initial assessment costs} = \sum (F_{\text{nurse}}, F_{\text{ref phys.}}, F_{\text{technologist}}, C_{\text{scanner}})
\]

\[
\text{Telephone consultation costs} = \sum (F_{\text{specialist}}, C_{\text{telephone}})
\]

Variable costs per patient for teleradiology consultation are:

\[
C_{V_{\text{Teleradiology}}} = \text{Initial assessment costs} + \text{Teleradiology consultation costs}
\]

\[
\text{Initial assessment costs} = \sum (F_{\text{nurse}}, F_{\text{ref phys.}}, F_{\text{technologist}}, C_{\text{scanner}})
\]

\[
\text{Teleradiology consultation costs} = \sum (F_{\text{TR ref phys.}}, F_{\text{TR specialist}}, C_{\text{telephone}}, C_{\text{transmission}}, C_{\text{non-surgical treatment}})
\]
Table 15 – Costing chart for fees and other direct costs associated with patients requiring neurosurgical assessments

<table>
<thead>
<tr>
<th>Costs associated with neurosurgical assessments</th>
<th>Variable</th>
<th>Unit</th>
<th>Telephone Consultation (w/o images)</th>
<th>Teleradiology Consultation (w/ images)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiographic examination</td>
<td>C raster</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone rate</td>
<td>C telephone</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-surgical treatment and stabilization</td>
<td>C non-surgical treatment</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image transmission</td>
<td>C transmission</td>
<td>Minute</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Nurse</td>
<td>F nurse</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referring physician</td>
<td>F ref phys</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging technologist</td>
<td>F technologist</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurosurgeon’s telephone consultation fee</td>
<td>F specialist</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referring physician’s teleradiology fee</td>
<td>F TR ref phys</td>
<td>Patient</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Neurosurgeon’s teleradiology consultation fee</td>
<td>F TR specialist</td>
<td>Patient</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Monthly telephone or teleradiology network charges</td>
<td>C telecommunications</td>
<td>System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment purchase and installation</td>
<td>C teleradiology system</td>
<td>System</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Software</td>
<td>C software</td>
<td>System</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>C maintenance</td>
<td>System</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

Key: w/o images=without image transfer; w/images=with image transfer; C=cost; F=fee; N/A=not applicable

Telephone and teleradiology consultations share the same initial assessment costs. The additional cost for teleradiology consultation is the difference between costs specific to telephone consultations and costs specific to teleradiology consultations. Variability and uncertainty in the consultation fees and costs are driven by referral patterns, utilization rates and duration of consultation sessions. Fixed costs are related to network service, acquisition or rental of teleradiology systems (work stations, monitors, picture archiving and communications systems, and other equipment), software, and telecommunications equipment
maintenance (and upgrade). These costs ($C_{Fixed} = C_{telecommunications} + C_{teleradiology system} + C_{software} + C_{maintenance}$) are not always incurred at a single point in time.

Fixed costs for a teleradiology system, software and telecommunications are usually amortized over five years while maintenance costs are incurred annually at 10% of the equipment purchase price (Caramella, 1996).

**Facilities:** Two of the NSUs from the Local Health Integrated Networks (LHINs) who received the most number of referrals in 2008/2009 will participate in the study. Toronto Western Hospital in LHIN 7 received 399 referrals, St. Michael’s Hospital in LHIN 7 received 375 referrals and Hamilton General Hospital in LHIN 4 received 336 referrals. These hospitals are expected to have well-established protocols for telephone consultations.

**Evaluation:** An estimate of the financial impact of a teleradiology network over a telephone consultation system can be calculated by subtracting the additional teleradiology costs ($C_{V\_Teleradiology} - C_{V\_Telephone} + C_{Fixed}$) from the costs avoided by reducing the patient transfer rate (Transportation costs + Hospitalization costs). Costs can be found prospectively using data collected during phase II or retrospectively using historical data from ORNGE (formerly the Ontario Air Ambulance) and from the Ontario Health Insurance Plan (OHIP). The simple costing chart in Table 16 can be used to summarize the transportation and hospitalization costs.
Table 16 – Costing chart for transportation and hospitalization of patients requiring neurosurgical assessments

<table>
<thead>
<tr>
<th>Transportation and hospitalization costs</th>
<th>Variable</th>
<th>Unit</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air transportation</td>
<td>$C_{air}$</td>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Ground transportation</td>
<td>$C_{Ground}$</td>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Hospitalization at NSU</td>
<td>$C_{NSU\text{ hosp}}$</td>
<td>Day</td>
<td></td>
</tr>
<tr>
<td>Hospitalization at RC</td>
<td>$C_{RC\text{ hosp}}$</td>
<td>Day</td>
<td></td>
</tr>
</tbody>
</table>

Key: NSU=neurosurgical unit, RC=referring centre

8.2 Limitations of the proposal

The main limitation is that the proposal does not outline a plan for convincing physicians to participate in the study. Physicians may be reluctant to participate because the majority of the patients involved are acutely ill, there are potential challenges associated with the logistics of ensuring randomization when such patients present at peripheral hospitals, and some physicians may be convinced that teleradiology is effective (even though the evidence supporting that belief is low quality). Furthermore, research ethics boards will have to waive the requirements to get informed consent from patients enrolled in the study. A secondary limitation is that there is a risk that the distribution of patient characteristics might be uneven between the teleradiology and telephone consultation groups. One group may, by chance, end up with patients with more serious conditions than the other group. Although it is clear that the risk of uneven assignments will decrease as the number of patients enrolled in the study increases, there is uncertainty about the length of time required to collect sufficient data to eliminate assignment bias.
9. CONCLUSIONS

Although the reviewed studies showed considerable subjective preference for teleradiology over telephone consultation, video-conferencing consultation, and assessments without consultation, the evidence was not strong enough to reliably quantify the impact of teleradiology. In addition, most of the evidence was not generalizable to Ontario.

A common theme in the studies was the assumption that the primary benefit that teleradiology brings to providers is the reduction in the proportion of transfers. As shown, several studies may have overstated the extent to which teleradiology reduced transfers while others failed to highlight the lower threshold for transfer rates. Most studies also failed to emphasize the importance of high quality, standardized protocols for remote telephone consultations. Furthermore, majority of the studies did not weigh the projected benefits in transportation and hospitalization savings against the technical and financial burden of implementing and maintaining a teleradiology network.

In order to quantify the impact of teleradiology in Ontario, primary data must be collected within the province. The suggested study proposal provides a framework for future teleradiology studies launched by the Ontario Ministry of Health and Long-Term Care.
10. DISCLOSURE

The author of this review is employed by a privately-held health technology assessment company.
11. REFERENCES


CritiCall Ontario data. Received via email from V. Alexis 2009.


Hersh WR et al. Clinical outcomes resulting from telemedicine interventions: a systematic review. BMC Med Inform Decision Mak 2001 (November); 1:5.


12. APPENDICES

Appendix A – Search parameters

The following search parameters were used:

1  e-mail/ or Internet/ or Mobile Phone/ or Telephone/ or Videoconferencing/ or Teleconference/ or exp Telehealth/
2  (tele-health$ or telehealth$).tw.
3  (tele-medicine$ or telemedicine$).tw.
4  (tele-communication$ or telecommunication$).tw.
5  (tele-consult$ or teleconsult$).tw.
6  (video-conferenc$ or videoconferenc$).tw.
7  ((remote or off-site or ofsite or distant$ or tele$ or web-based or web based or Internet or web or computer-assisted or computer assisted or rural or non-urban or under-served or underserved or under served) adj2 consult$).tw.
8  or/1-7
9  Radiology/
10  Diagnostic Imaging/ or Fluoroscopy/ or exp Nuclear Magnetic Resonance Imaging/ or exp Radiography/ or exp Tomography/ or exp Whole Body Imaging/ or X Ray/
11  diagnostic imag$.tw.
12  radiology.tw.
13  radiography.tw.
14  x-ray.tw.
15  tomography$.tw.
16  or/9-15
17  8 and 16
18  teleradiology/
19  (tele-radiolog$ or teleradiolog$).tw.
20  or/18-19
21  17 or 20
Appendix B – Quality assessment checklists

Quality criteria from the National Health Services Centre for Reviews and Dissemination guidance document for assessing observational studies (Kahn et al., 2001):
1. Is the study based on a representative sample selected from a relevant population?
2. Are the criteria for inclusion explicit?
3. Did all individuals enter the survey at a similar point in their disease progression?
4. Was follow-up long enough for important events to occur?
5. Were outcomes assessed using objective criteria or was blinding used?
6. If comparisons of sub-series are being made, was there sufficient description of the series and the distribution of prognostic factors?

A checklist published by Verhagen et al. (1998) to evaluate randomized controlled trials:
1. Was a method of randomization performed?
2. Was the treatment allocation concealed?
3. Were the groups similar at baseline regarding the most important prognostic indicators?
4. Were the eligibility criteria specified?
5. Was the outcome assessor blinded?
6. Was the care provider blinded?
7. Was the patient blinded?
8. Were point estimates and measures of variability presented for the primary outcome measures?
9. Did the analysis include an intention-to-treat analysis?

A checklist by Drummond et al. (1997) was used for evaluating cost-effectiveness analyses:
1. Were there comprehensive descriptions of the intervention and comparator(s)?
2. Were all important and relevant costs and outcomes for each option identified?
3. Were costs and outcomes measured accurately and consistently across comparator(s)?
4. Were costs and outcomes valued credibly?
5. Were costs and outcomes adjusted for differential timing?
6. Was there an incremental analysis of costs and consequences?
7. Were sensitivity analyses conducted to investigate uncertainty in estimates of cost or consequences?
### Study details

<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bailes, J (1997)</strong></td>
<td><strong>Type of study:</strong> Prospective, comparative case series</td>
<td><strong>Eligibility:</strong> Pts admitted w/ abnormal neuroradiologic findings, neurological examination or both.</td>
<td><strong>Intervention group, n=100 pts</strong></td>
<td><strong>Benefits/disadvantages of TR:</strong> Other benefits included changes to the pt pathway for urgent surgeries (n=5) on arrival at NSU. TR equipment cost USD12,000 to 20,000 ($16,562 to 27,536), display software cost USD900 ($1239) on average per hospital, and telephone charges included USD35 ($48) per month and 10 cents a minute for usage.</td>
</tr>
<tr>
<td><strong>Objective of study:</strong> To evaluate the potential cost savings of using the Neurolink® TR network</td>
<td><strong>Intervention (TR option):</strong> Consultation between emergency department physicians (67%), other referring physicians at RC and on-call neurosurgeons at NSU for pts w/ intracranial hemorrhage (n=39), spinal injury (n=18), tumor (n=14), stroke (n=8), and head injury/headache (n=21).</td>
<td><strong>Image transmission:</strong> MR (n=3), CT (n=96) and cerebral angiography (n=1) images were converted to digital format by a video framegrabber; images were transferred at 14.4 kbit/s over dedicated telephone lines and displayed on a 14- or 21-inch PC monitor at resolutions up to 1024 X 1024 pixel.</td>
<td><strong>Transfers:</strong> 67 (67%) pts by helicopter (n=25) and ground transportation (n=42)</td>
<td>TR enabled neurosurgeons to recommend that 38 pts be transferred by road. Four pts assigned to air transportation were transferred by ground due to weather conditions.</td>
</tr>
<tr>
<td><strong>Provider profiles:</strong> The NSU was Allegheny General Hospital in Pittsburgh, Pennsylvania, USA. There were 20 RCs in Western Pennsylvania, USA. The NSU was a tertiary care hospital and the RCs were community hospitals.</td>
<td><strong>Comparator (Non-TR option):</strong> Pts were routinely transferred to NSU as a conservative approach (not studies).</td>
<td><strong>Transportation costs:</strong> Air transportation + USD41,280*</td>
<td><strong>Hospitalisation costs:</strong> USD309,250**</td>
<td><strong>Study limitations:</strong> Comparison was theoretical. Omitted some direct costs related to TR</td>
</tr>
<tr>
<td><strong>Eligibility:</strong> Pts admitted w/ abnormal neuroradiologic findings, neurological examination or both.</td>
<td><strong>Pt Evaluation Protocol:</strong> On-call neurosurgeon at NSU made transfer decisions after reviewing images sent via TR network</td>
<td><strong>Savings:</strong> USD502,638 compared to non-TR option. Includes USD90,750 for hospitalising 33 pts at RC rather than at NSU, USD227,454 for not transferring 33 pts (by air) and USD184,434 for transferring 38 pts by ground rather than by air</td>
<td><strong>Hospital length of stay was estimated from averages of pts previously admitted to the NSU.</strong></td>
<td><strong>General comments:</strong> Transportation costs varied among hospitals. Pts were consecutively recruited.</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Intervention: Transportation costs: $192,336** Hospitalisation costs: $309,250 (67 x $4,000 + 33 x $1,250) Comparator: Transportation costs: 100 pts at $225,714/38 per pt (estimate by air) Hospitalisation costs: $400,000 (100 x $4,000) **Estimated air transportation costs for 25 pts at a rate of $225,714/38 per pt</td>
</tr>
<tr>
<td><strong>Study details</strong></td>
<td><strong>Patients/Intervention/ Comparator(s)</strong></td>
<td><strong>Methodology</strong></td>
<td><strong>Outcome(s)</strong></td>
<td><strong>Comments</strong></td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Goh, KY (1997a)</td>
<td><strong>Eligibility:</strong> 116 pts consecutively referred to NSU from March to December 1995 with mass lesions (n=32), DHI (n=26), subarachnoid hemorrhage events (n=11), ICH (n=37), tumours (n=7) and other events (n=3).</td>
<td><strong>Image transmission:</strong> CT images were transmitted by the referring physician via telephone line. Images were viewed using Multiview TR for Windows 2.0 on a personal computer and on a portable computer by the neurosurgical team on-call.</td>
<td><strong>Intervention group, n=66 pts</strong></td>
<td><strong>Benefits/disadvantages of TR:</strong> TR link caused reduction in transfers, morbidity and mortality by 21%, 26%, and 12% respectively; neurosurgeons were able to correct three wrong diagnoses: one for subarachnoid haemorrhage diagnosed as viral encephalitis, one for a third ventricular tumour diagnosed as intraventricular haemorrhage, and one for intraventricular blood in the third and fourth ventricles diagnosed as a cerebellar haematoma. Neurosurgeons suggested intervention in more pts (26.9% compared to 20%); lower rate of adverse events indicates better communication between physicians.</td>
</tr>
<tr>
<td><strong>Type of study:</strong> Comparative case series</td>
<td><strong>Intervention (TR option):</strong> Consultations for mass lesions (n=16), DHI (n=14), subarachnoid haemorrhage events (n=7), ICH (n=22), tumours (n=5) and other events (n=2). Consultations included telephone communication.</td>
<td><strong>Pt Evaluation Protocol:</strong> All pts were evaluated on the GCS at admission. All eligible pts were transferred by ground transportation after safe transfer checklist was filled. Pts were evaluated on GCS by neurosurgeon on admission to NSU. Outcome of each pt was defined on the GOS after 1 month.</td>
<td><strong>Changed diagnosis:</strong> 3 (5%) pts</td>
<td></td>
</tr>
<tr>
<td><strong>Objective of study:</strong> To evaluate diagnostic accuracy, change in pt mgmt, morbidity and mortality w/ TR compared to telephone consultations</td>
<td><strong>Comparator (Non-TR option):</strong> Telephone consultations for mass lesions (n=16), DHI (n=12), subarachnoid haemorrhage events (n=4), ICH (n=15), tumours (n=2) and other events (n=1).</td>
<td><strong>Diagnostic accuracy was defined as agreement between referring physician and neurosurgeon on CT findings and clinical data. Therapeutic intervention was defined as additional measures indicated by the neurosurgeon prior to transfer. Adverse events were events w/ the potential to affect outcome.</strong></td>
<td><strong>Changed pt mgmt:</strong> 14 (21%) pts had additional procedures such as endotracheal intubation</td>
<td></td>
</tr>
<tr>
<td><strong>Provider profiles:</strong> The NSU was Prince of Wales Hospital at The Chinese University in Hong Kong — 1400-bed tertiary referral centre serving a population of 1.5 million. There were 2 RCs - district general hospitals — in Hong Kong</td>
<td></td>
<td><strong>Transfers:</strong> 52 (79%) pts</td>
<td><strong>Mortality:</strong> 1 (2%) pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Morbidity:</strong> 3 (5%) pts w/ disability (2 severe, 1 moderate)</td>
<td><strong>Adverse events:</strong> 4 (6%) pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Comparator group, n=50 pts</strong></td>
<td><strong>Comparator group, n=50 pts</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Changed diagnosis:</strong> NR</td>
<td><strong>Changed diagnosis:</strong> NR</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Changed pt mgmt:</strong> 10 (20%) pts</td>
<td><strong>Changed pt mgmt:</strong> 10 (20%) pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Transfers:</strong> 50 (100%) pts</td>
<td><strong>Transfers:</strong> 50 (100%) pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Morbidity:</strong> 9 (18%) pts w/ disability (4 severe, 5 moderate)</td>
<td><strong>Morbidity:</strong> 9 (18%) pts w/ disability (4 severe, 5 moderate)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Mortality:</strong> 7 (14%) pts</td>
<td><strong>Mortality:</strong> 7 (14%) pts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Adverse events:</strong> 16 (32%) pts</td>
<td><strong>Adverse events:</strong> 16 (32%) pts</td>
<td></td>
</tr>
</tbody>
</table>

**General comments:** Pt population overlaps w/ Goh et al. 1997b. Overlap of authors w/ Goh et al 1997b, Poon et al. 2001, and Wong et al 2006. Emphasizes the importance of focusing on non-surgical pt management prior to and during transfer.
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goh, KY (1997b)</td>
<td>Eligibility: 63 pts admitted between March 1995 and May 1996 w/ EDH (n=10), acute SDH (n=9), chronic SDH (n=1), ICH or contusions (n=17), DHI (n=13), and NR (n=13).</td>
<td>Image transmission: CT images were transmitted over a telephone line and viewed on a personal computer workstation.</td>
<td>Intervention group, n=35 pts  Changed diagnosis: 1 (~0%) pt  Changed pt mgt: 10 (29%) pts  Transfers: 31 (89%) pts  Morbidity: 9 (26%) pts were vegetative (n=3), w/ disability (1 severe, 5 moderate)  Mortality: 5 (14%) pts  Adverse events: 2 (6%) pts w/ hypotension (n=1), missed injury (n=1)  Pt transfer time: 72 minutes</td>
<td>Benefits/disadvantages of TR: Presence of traumatic subarachnoid blood missed by referring physician in 1 pt in the intervention group, had no impact on pt management; incidence of secondary insults was significantly less w/ TR (P=0.017). No statistical difference in outcome. Requires randomized controlled trial (may be faced w/ ethical issues). Telephone consultations have been fraught w/ issues. 26 pts w/ normal CT scans were transferred (13 DHI and 10 required ICP management).</td>
</tr>
<tr>
<td>Provider profiles: The NSU was Prince of Wales Hospital at The Chinese University in Hong Kong –1400-bed tertiary referral centre serving a population of 1.5 million. There were 2 RCs - district general hospitals – in Hong Kong.</td>
<td>Intervention (TR option): Consultation between referring physician and on-call neurosurgeon for pts w/ EDH (n=6), acute SDH (n=4), chronic SDH (n=1), ICH or contusions (n=7), DHI (n=5), and NR (n=12); mean GCS=12.5 (range 3-15). Consultations included telephone communication.</td>
<td>Pt Evaluation Protocol: Eligible pts were transferred by ground transportation after safe transfer checklist was filled out. Clinical details were discussed over the phone. Admitting neurosurgeon evaluated pt outcome based on GOS.</td>
<td>Comparator group, n=28 pts  Changed diagnosis: 1 (~0%) pt  Changed pt mgt: 3 (10.7%) pts  Transfers: 28 (100%) pts  Morbidity: 9 (32%) pts were vegetative (n=2), w/ disability (3 severe, 4 moderate)  Mortality: 4 (14%) pts  Adverse events: 9 (32%) pts w/ hypoxia and hypotension (n=2), neurological deterioration (n=5), convulsions (n=1), missed injury (n=1)  Pt transfer time: 80 minutes</td>
<td></td>
</tr>
<tr>
<td>Type of study: Comparative case series</td>
<td>Comparator (Non-TR option): Telephone consultation for pts w/ EDH (n=4), acute SDH (n=5), ICH or contusions (n=10), DHI (n=8), NR (n=1); mean GCS=11.2 (range 3-15)</td>
<td>Prospective data was collected on diagnostic accuracy, therapeutic intervention after consultation, adverse events during transfer, and outcome.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective of study: To assess the impact of TR on the management of pts w/ head injuries</td>
<td>Diagnostic accuracy was defined as agreement between referring physician and neurosurgeon on CT findings and clinical diagnosis. Therapeutic intervention was defined as additional measures indicated by the neurosurgeon prior to transfer. Adverse events were events w/ the potential to affect outcome.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General comments: Pt population overlaps w/ Goh et al. 1997a; authors overlap w/ Goh et al 1997a, Poon et al. 2001, and Wong et al 2006. Size of study population compared to previous shorter study implies that pts were selected although authors indicate selection was consecutive;
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/ Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heautot, J-F (1999)</td>
<td>Eligibility: 108 pts enrolled sequentially over 18 months</td>
<td>Image transmission: CT and MR images were digitized w/ a film digitizer, and transmitted via 64 kbit/s ISDN link w/out interactive discussion (phase II) or w/ 34 Mbps ATM link and video-conferencing (phase III). Images were reviewed on a personal computer.</td>
<td>Intervention group, n=51 pts Response time: NR Changed pt management: 10 (20%) pts (estimated) Transfers: 34 (65%) pts Unnecessary transfers: 2 (2%) pts Cost: $48,48 (£20) per month + 18 cents (7.5 pence) per 30 seconds* Neurosurgeons rated technical performance as very good (56%), and good (44%) Comparator group 1, n=11 pts Response time: NR Changed pt management: NR Transfers: 10 (91%) pts Unnecessary transfers: 4 (36%) pts Comparator group 2, n=46 pts Response time: 11.7 ± 10.9 minutes Changed pt management: 23 (50%) pts (estimated) Transfers: 29 (63%) pts Unnecessary transfers: NR Neurosurgeons rated technical performance as very good (11%), good (55%), acceptable (27%) and bad (22%)</td>
<td>Benefits/disadvantages of TR: Estimated that 8/51 additional transfers would have been made in phase II if TR link was unavailable. Neurosurgeons reported usefulness of transmitted images in 50% of cases in phase III. RC physicians used TR link to confirm decisions regarding pt transfers and increased the number of non-urgent consultations Video-conferencing may have been under-utilized due to long set-up times. Cost of ATM link was $218160 (£90,000) over 2 years.</td>
</tr>
<tr>
<td>Type of study: Retrospective, case-control study (Three phases)</td>
<td>Intervention (TR option): Consultation between emergency department physician and radiologists or residents at neurosurgery unit w/ TR link for 6 months (phase II). Consultations included telephone communication.</td>
<td>Pt Evaluation Protocol: Decisions on pt transfers were made by consent. Neurosurgery resident reported whether images changed pt management decision. Physicians filled out questionnaires. Comparator evaluation: Neurosurgeon documented whether images would have made a difference in decisions (phase I).</td>
<td>Comparator evaluation: Neurosurgeon documented whether images would have made a difference in decisions (phase I).</td>
<td></td>
</tr>
<tr>
<td>Objective of study: To evaluate the impact of TR on neurosurgical consultations</td>
<td>Comparator (Non-TR option): (1) Telephone consultation between emergency department physician and neurosurgery resident for 4.5 months prior to implementation of TR link. Images were sent via post for pts that were not transferred (phase I), and (2) consultation w/ TR link and video-conferencing for 6 months (phase III).</td>
<td>Comparator group 1, n=11 pts Response time: NR Changed pt management: NR Transfers: 10 (91%) pts Unnecessary transfers: 4 (36%) pts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provider profiles: The NSUs were university hospitals – ETIAM SA and Service de Neurochirurgie – in CHU Pontchaillou, Rennes, France. The RC was a large, level 2 trauma centre, w/ intensive care and neurology departments. 100km from the NSU.</td>
<td></td>
<td>Comparator group 2, n=46 pts Response time: 11.7 ± 10.9 minutes Changed pt management: 23 (50%) pts (estimated) Transfers: 29 (63%) pts Unnecessary transfers: NR Neurosurgeons rated technical performance as very good (11%), good (55%), acceptable (27%) and bad (22%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*April 1, 1999 conversion rate
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/ Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houkin, K (1999)</td>
<td>Type of study: Retrospective, case-control study</td>
<td><strong>Eligibility:</strong> Pts w/ brain tumours (n=5), cerebrovascular disease (n=5) and spinal disorder (n=2)</td>
<td><strong>Image transmission:</strong> MR images, CT scans, digital subtraction angiograms and radiographs of the skull were digitized w/ a charge coupled device and transmitted over 64 kbit/s ISDN line.</td>
<td><strong>Intervention group, n=12 pts</strong>&lt;br&gt;Response time: 3 minutes per pt (image transfer) + 15 minutes (discussion)&lt;br&gt;Cost of consultation: ¥3420 ($47.58)<em>&lt;br&gt;Comparator group, n=NR pts&lt;br&gt;Response time: 4 days one-way by express mail&lt;br&gt;Cost of mailing films: ¥3500 ($48.69)&lt;br&gt;</em> January 1, 1999 conversion rate</td>
</tr>
<tr>
<td><strong>Objective of study:</strong> To evaluate the quality of images, cost and time performance of a TR system compared to conventional methods</td>
<td><strong>Provider profiles:</strong> NR.</td>
<td><strong>Pt Evaluation Protocol:</strong> Neurosurgeon confirmed diagnosis. Verbal communication occurred simultaneously w/ image review.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Provider profiles:</strong> The NSU was Hokkaido University School of Medicine, Japan and the RC was Universiti Kebangsaan Malaysia, School of Medicine, Malaysia</td>
<td><strong>Intervention (TR option):</strong> Consultations included telephone communication.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Comparator (Non-TR option):</strong> Consultations using mail to transport films and fax to transmit written communication.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study details</td>
<td>Patients/Intervention/ Comparator(s)</td>
<td>Methodology</td>
<td>Outcome(s)</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Kreutzer, J (2008)</td>
<td>Eligibility: 1024 pts w/ ICH (510), trauma (280), hydrocephalus (n=27), tumour (n=80), SAH (n=44), stroke (n=48), and miscellaneous (n=35) referred to NSU between 1995 and 2000.</td>
<td>Image transmission: CT and MR images were transmitted over analog telephone line at 19,200 baud rate.</td>
<td>Intervention group, n=1024 pts Transfers: 330 (29%) pts Unnecessary transfers: 105 (10%) Morbidity: 93 (39%) pts Mortality: NR (4% of transferred pts died) pts Average savings: €151,977 ($219,448) to €382,972 (552,995) estimated* Costs: €12,000 ($17,326) for equipment</td>
<td>Benefits/disadvantages of TR: There were no additional system costs over 5 years Study limitations: Did not report costs of transporting 330 pts; description of image transmission process was incomplete.</td>
</tr>
<tr>
<td>Type of study: Retrospective, comparative case series</td>
<td>Intervention (TR option): Consultations included telephone communication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective of study: To evaluate technical stability, reliability and cost of TR system</td>
<td>Comparator (Non-TR option): No consultation. All pts were transferred (not studied).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provider profiles: The NSU was at the University of Erlangen-Nuremberg in Germany were approximately 2200 neurosurgical surgeries are performed each year. 17 hospitals in Northern Bavaria, Germany served as RCs. They did not have neurosurgical consultants.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study details</td>
<td>Patients/Intervention/ Comparator(s)</td>
<td>Methodology</td>
<td>Outcome(s)</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| Maass, M (2000) | **Type of study:** Retrospective, comparative case series  
**Objective of study:** To evaluate transportation savings and clinical benefits of TR  
**Provider profiles:** The NSU was Turku University Central Hospital in Finland. Since 1996 the NSU has provided TR consultations to RCs in Åland, Salo, and Satakunta. The regional hospitals were located 160km, 60km and 140km away, respectively. Åland was situated on an island. The RCs did not have neurosurgical or neurological specialists.  
**Eligibility:** Pts w/ subarachnoid haemorrhages admitted to Åland (n=7), Salo (n=40), and Satakunta (n=36) hospitals in 1998.  
**Intervention (TR option):** Consultations between NSU and RCs.  
**Comparator (Non-TR option):** Pts were routinely transferred w/out consultation (not studied).  
**Image transmission:** CT images of the brain were transmitted to NSU.  
**Pt Evaluation Protocol:** Decisions were made by the local physician. Transportation costs were obtained from accounting departments.  
**Intervention group, n=83 pts**  
Transfers: 16 (19%) pts from Åland (n=2), Salo (n=2), and Satakunta (n=12)  
Unnecessary transfer: 1 (1%) pt from Satakunta  
Mortality: 3 (3.7%) pts (2 w/ brain infarct and 1 w/ ICH at Åland)  
Transportation costs: 27,700 ECU($46,808) from Åland (24,300 ECU), Salo (400 ECU), and Satakunta (3000 ECU)*  
**Comparator group, n=83 pts**  
Transfers: 100% (not measured)  
Transportation costs: Estimated at 69,800 ECU ($117,948) from Åland (52,800 ECU), Salo (8,000 ECU), and Satakunta (9000 ECU)  
* January 1, 2000 conversion date  
**Benefits/disadvantages of TR:** Transportation savings: 42,100 ECU ($71,141) for Åland (28,500 ECU), Salo (7,600 ECU), and Satakunta (6000 ECU)  
**Study limitations:** Comparison was done theoretically. No actual pts were enrolled in a non-TR group. There was no data on clinical benefits. Image transmission process was not described.  
**General comments:** Cost of TR consultations: 12,948 ECU ($21,880) for Åland (1,092 ECU), Salo (6,240 ECU), and Satakunta (5,616 ECU); includes network rental costs, maintenance, local personnel time and NSU reporting charge (56 ECU per pt ($98)), but excludes equipment costs  
Cost of CCD film scanner at Åland was 25,000 ECU ($42245).  
Consultations included pts w/ normal CT scans (n=30). Only 1 was transferred (unnecessarily) to NSU. Excluding pts with normal CT, transfer rate, unnecessary transfers, and mortality rate for intervention would be 28%, 0%, and 5.7%.
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/ Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poon, WS (2001)</td>
<td>Eligibility: Pts w/ head injury (n=87), cerebrovascular accident (n=159) and miscellaneous events (n=81) requiring neurosurgical diagnoses between October 1998 and July 1999.</td>
<td>Image transmission: CT images were converted using analog video framegrabbing and audio-visual images were converted into digital signals. Data was transmitted via two ISDN lines at 256 kbit/s.</td>
<td>Overall, n=269 pts&lt;br&gt;Transfers: 127 (38%) pts&lt;br&gt;Intervention group, n=167 pts&lt;br&gt;Response time: 49.2 min (includes 13.2 min consultation time)&lt;br&gt;Morbidity: 69.2% (30.8% favourable clinical outcome*)&lt;br&gt;Comparator group 1, n=59 pts&lt;br&gt;Response time: 1.8 min (includes consultation time)&lt;br&gt;Morbidity: 61.8% (38.2% favourable clinical outcome)&lt;br&gt;Comparator group 2, n=101 pts&lt;br&gt;Response time: 65.4 min (includes 10.2 min consultation time)&lt;br&gt;Morbidity: 56.5% (43.5% favourable clinical outcome)</td>
<td>Benefits/disadvantages of TR: Response time was better than w/ video-conferencing but longer compared to telephone consultations. No significant difference in morbidity rates.</td>
</tr>
<tr>
<td>Type of study: Prospective, randomized controlled trial</td>
<td>Intervention (TR option): Consultation initiated by telephone (mode B) Comparator (Non-TR option): (1) Conventional telephone consultation (mode A), and (2) real-time audio-visual teleconferencing (mode C)</td>
<td>Pt Evaluation Protocol: Transfer decisions were made by the neurosurgeon on call. Pt outcome was recorded on GOS scale.</td>
<td>*Favourable clinical outcome means GCS≥4&lt;br&gt;Comparator group 1, n=59 pts&lt;br&gt;Response time: 1.8 min (includes consultation time)&lt;br&gt;Morbidity: 61.8% (38.2% favourable clinical outcome)</td>
<td>Study limitations: Randomization process was not described. Pts were not sufficiently segmented in disease categories; 56 failed cases (video-conferencing (n=54), and teleradiology (n=2)) due to technical problems were excluded from the study; 2 additional cases were excluded w/o explanation; unstable pts were excluded from analysis leading to selection bias. Statements on reduction of number of unnecessary transfers, and discrepancy between neurological status of pts after transfer compared to information received on the phone from referring physicians were not supported by data.</td>
</tr>
<tr>
<td>Provider profiles: The NSU was the Prince of Wales Hospital at The Chinese University in Hong Kong – a 1400-bed teaching hospital serving a population of 2 million. The RCs were Alice Ho Mui Ling Hospital and the United Christian Hospital in Hong Kong.</td>
<td>Comparator group 2, n=101 pts&lt;br&gt;Response time: 65.4 min (includes 10.2 min consultation time)&lt;br&gt;Morbidity: 56.5% (43.5% favourable clinical outcome)</td>
<td>General comments: Overlap of authors w/ Goh et al 1997a, Goh et al 1997b, Wong et al 2006 (w/ possible overlap of pts w/ the latter). Setup time was 36 min for TR compared to 55 min for audio-visual consultations. Based on reported failure rates, sample sizes were calculated as 167 in the intervention group, 59 in the telephone consultation group and 101 in the video-conferencing group.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study details</td>
<td>Patients/Intervention/ Comparator(s)</td>
<td>Methodology</td>
<td>Outcome(s)</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Stormo, A (2004)</td>
<td>Eligibility: 91 pts requiring 99 consultations for intracranial tumours (n=29), acute cerebrovascular disease (n=29), head injuries (n=18), spinal disease (n=12) and miscellaneous events (n=11) admitted at rural hospitals from September 1999 to May 2000</td>
<td>Image transmission: CT, MR, and cervical spine radiography images were transmitted via IP protocol at 32 Mbit/s and made available through a web interface</td>
<td>Intervention group, n=99 cases Response time: 3 hrs (range 1 to 21 hrs) for emergencies (n=36); 1 day (range, 107 days) for ordinary consultations (n=12) Changed pt management: 42 (42%) cases received pharmacological treatment (n=11), supplementary radiographic imaging (n=27); withdrawal of support because of dismal prognosis (n=3), and spinal surgery (n=1) Transfers: 46 (46%) cases (20 w/in a day of consultation) Unnecessary transfers: 34 (34%) pts</td>
<td>Benefits/disadvantages of TR: Beneficial in 93% cases Study limitations: Response time was recorded for only 48 consultations; outcome of transfers were not reported; statements indicating that TR reduces frequency of transfers were not supported by data because a comparator group was not evaluated. Negative impact of TR was not provided as an option on the consultation form.</td>
</tr>
<tr>
<td>Type of study: Prospective, case series</td>
<td>Intervention (TR option): Consultations initiated via telephone by physicians at RCs. Comparator (Non-TR option): None</td>
<td>Pt Evaluation Protocol: Neurosurgery residents filled out registration forms for each consultation. Images could be accessed from home. Physicians reported clinical condition and response time (from enquiry to feedback)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective of study: To evaluate the effect of TR on pt mgt decisions made by local physicians</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provider profiles: The NSU was University Hospital of North Norway in Tromsø, Norway – a university hospital serving a population of 460,000. The RCs were 10 rural hospitals in Nordland, Troms and Finnmark counties in Norway, w/o neurosurgery or neurology specialists.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study details</td>
<td>Patients/Intervention/Comparator(s)</td>
<td>Methodology</td>
<td>Outcome(s)</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Urban, V (1996)</td>
<td>Pts w/ intracerebral bleeding (n=138), intracranial tumours (n=86), head trauma (n=47), vascular malformations (n=29), aneurysms (n=23) and miscellaneous events (n=70) from January 1991 to December 1994</td>
<td><strong>Image transmission:</strong> CT (n=303), MR (n=73), angiography (n=12), and X-Ray (n=5) images were transmitted via fibre optic cable network (VBN) at a rate of 140 Mbit/s (n=34) and telephone lines (n=398). Images were reviewed on digital monitors.</td>
<td><strong>Intervention group, n=393 pts</strong>&lt;br&gt;Response time: 15 min (range 4 to 50 minutes)&lt;br&gt;Transfers: 161 (41%) pts</td>
<td><strong>Benefits/disadvantages of TR:</strong>&lt;br&gt;TR is not always the best option for transmitting images; poor image quality and compatibility issues may be a concern; only 15.9% of transferred pts required surgery&lt;br&gt;&lt;br&gt;<strong>Study limitations:</strong> Conclusions indicating that TR can decrease emergency travel distances and treatment times were not supported by data because a comparator group was not evaluated. The process of evaluating images or making transfer decisions was not described.&lt;br&gt;&lt;br&gt;Error in percentage calculation for 161 pts (reported 33.3% instead of 41%) requiring transfer; data in the text did not always match data in the table&lt;br&gt;&lt;br&gt;<strong>General comments:</strong>&lt;br&gt;There were 432 consultations done on 393 patients. Multiple consultations (&lt;5) were recorded for 31 patients.</td>
</tr>
</tbody>
</table>

*Type of study:* Retrospective, case series

*Objective of study:* To report on the results of implementing a TR network

*Provider profiles:* The NSU was University of Mainz, Department of Neurosurgery, Germany. TR link was supported by the government of Rheinland-Pfalz and an international video company. RCs were large clinics (n=7) and small neurosurgical departments (n=2) in Germany.
Wong, H (2006)

Type of study: Prospective randomized controlled trial

Objective of study: To investigate the existence of clinical differences between TR, telephone and video consultation, and the associated cost-effectiveness

Provider profiles: The NSU was the Prince of Wales Hospital at The Chinese University in Hong Kong – a 1400-bed tertiary referral centre serving a population of 1.5 million. The RC was the United Christian Hospital in Hong Kong – a large district general hospital.

Eligibility: 710 pts consecutively referred to NSU from October 1998 to September 2001 w/ head injury and GCS ≤ 14 and/or evidence of intracranial fracture or intracranial injury (n=224), stroke w/ evidence of intracranial hemorrhage (n=327), or symptoms and signs of increased intracranial pressure or focal neurological deficit - including brain tumour, hydrocephalus, brain abscess, and chronic subdural hematoma (n=159).

Intervention (TR option): Consultations including telephone communication initiated by emergency department or by other referring physicians.

Comparator (Non-TR option): (1) Telephone consultation reporting on case history, physical signs and relevant investigations, and (2) video-conferencing via low-cost real-time video over 256 kbps ISDN line.

Image transmission: CT images were transmitted via Multiview TR for Windows 2.0

Pt Evaluation Protocol: Patients were randomized by double-sealed envelopes into three groups. Recommendations by neurosurgeons were documented. Pts were transferred following standard protocol and re-assessed for neurological deterioration after transfer. Independent evaluation of transferred pts on arrival at NSU by neurosurgeon to determine unnecessary transfer rate. All pts were re-assessed by mobile neurosurgical team for diagnostic accuracy. Pts were followed up at 1 month and 6 months after admission and evaluated on the GOS.

Intervention group, n=239 pts
Response time (±SD): 1.01 ± 1.8 hrs (longer than group 1, p=0.003, comparable to group 2, p=0.147)
Diagnostic accuracy: 26 (11%) pts
Transfers: 69 (29%) pts
Unnecessary transfers: 11 (5%)
Morbidity: 93 (39%) pts at 6 months
Mortality: 59 (25%) pts
Average cost: HKD14,455 ($2060)*

Comparator group 1, n=235 pts
Response time (±SD): 0.7 ± 1.9 hrs
Diagnostic accuracy: 84 (36%) pts
Transfers: 84 (36%) pts
Unnecessary transfers: 9 (4%)
Morbidity: 89 (46%) pts
Mortality: 81 (34%) pts
Average cost: HKD14,075 ($2006)

Comparator group 2, n=236 pts
Response time (±SD): 1.3 ± 2.5 hrs
Diagnostic accuracy: 29 (12%) pts
Transfers: 84 (36%) pts
Unnecessary transfers: 7 (3%)
Morbidity: 90 (46%) pts
Mortality: 79 (33%) pts
Average cost: HKD16,370 ($2333)

* September 1, 2006 conversion date

Benefits/disadvantages of TR:
Response time was comparable to video-conferencing (p=0.147) but longer than telephone (p=0.003). No significant difference in transfer rates. Lower failure rate (3.8%) than video-conferencing (30.1%) and telephone (9%). Video-conferencing failures were due to logistical problems whereas telephone failures were due to requests by physicians for images. Mortality rates w/ TR were lower than w/ telephone, p=0.025, and w/ video-conferencing, p=0.043.

Study limitations: May include pts reported by Poon et al (2001).

General comments: overlap of authors w/ Goh et al 1997a, Goh et al 1997b, and Poon et al 2001 (w/ possible overlap of pts w/ the latter).
<table>
<thead>
<tr>
<th>Study details</th>
<th>Patients/Intervention/ Comparator(s)</th>
<th>Methodology</th>
<th>Outcome(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zulu, BM (2007)</td>
<td><strong>Type of study:</strong> Prospective, case series (two-phase study) <strong>Objective of study:</strong> To assess the outcome of pts w/ head injuries <strong>Provider profiles:</strong> The NSU was Wentworth Hospital at the University of KwaZulu-Natal in Durban, South Africa – a 106-bed hospital providing the only public neurosurgical services to a population of 8.4 million. The RC, King Edward VIII Hospital in Durban, South Africa, had a general surgery unit and was located 8 km from the NSU.</td>
<td><strong>Eligibility:</strong> Pts w/ head injury severe enough (loss of consciousness, neurological deficit, or GCS&lt;15) to warrant admission to hospital and a CT scan from July 1997 to December 1998 (pilot study) and January to June 2001 (main study). <strong>Intervention (TR option):</strong> Consultations b/w local physician in general surgery unit at RC and neurosurgeon at NSU. <strong>Comparator (Non-TR option):</strong> Interpretation of images by local radiologist at RC</td>
<td><strong>Image transmission:</strong> CT images were transmitted by TR link. <strong>Pt Evaluation Protocol:</strong> All pts w/ GCS ≤ 14, any level of unconsciousness associated w/ neurological deficit, or failure to improve GCS above 15 had a CT scan; all transfers were done after consultation w/ neurosurgeon at NSU; pts w/ compound injury and/or oozing brain matter were immediately transferred w/out consultation. <strong>Intervention group, n=189 pts</strong> Transfers: 51 (27%) pts Unnecessary transfers: 0 pts Morbidity: 60 pts (32%) including 23 pts w/ serious sequelae such as hemiparesis (n=6), monoparesis (n=5), hemiplegia (n=3), hemiparesis (n=7) and monoparesis (n=2) Mortality: 32 (17%) pts during transfer (n=2), at NSU (n=9), and at RC (n=21) <strong>Comparator group, n=NR pts</strong> NR</td>
<td><strong>Benefits/disadvantages of TR:</strong> None of the deaths were considered preventable; 9/127 (7.1%) pts w/out CT scans died at RC compared to TR rate of 17%. <strong>Study limitations:</strong> Data was not reported for comparator. Only 189 of 316 pts had diagnostic imaging done. Image transmission process was not described. Did not describe process supporting statement that all deaths were unpreventable.</td>
</tr>
</tbody>
</table>