

Telemedicine in the Management of Head Trauma: An Overview

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Abstract : This article reviews the successful utilization of telemedicine in managing head trauma. Telemedicine has made geography history and distance meaningless. It can be a major tool in providing expertise for the management of neurotrauma cases, in far away areas. With the digital divide reducing in India, telemedicine should be considered a method to overcome the shortage of neuro-traumatologists. Following a discussion of the relevance of telemedicine in the Indian context and after outlining the author's personal experience, the world literature is reviewed.

Keywords : Telemedicine, Head injuries, neurotrauma

Head injuries are universally a public health hazard. India, which also has the maximum number of two wheelers, constitutes one sixth of humanity. A fatality every four minutes, makes head injury the sixth commonest cause of death in India. Only 800 neurosurgeons are available for a population of 1075 million, out of which 620 million live in rural India with no direct access to immediate neurosurgical care. Though 100-120 new neurosurgeons qualify every year from 50 teaching programmes this is not enough. Only 105 out of 160 medical colleges have neurosurgery departments. There are less than 12 state of the art neurotrauma critical care units in India. Neurosurgeons practicing in the metros and cities are reluctant to relocate to suburban and rural India.

At the same time India's progress in ICT (Information and Communication Technology) has been phenomenal. There are already 30 million mobile phone users. Forty five Internet services providers (ISPs) provide direct access to the internet to at least 200 million. Cyber cafes providing Internet connectivity are now available even in small towns. Personal computers are being increasingly used in urban homes and offices. ISDN telephone lines are readily available on demand in almost all the 530 district head quarters. There are more than than 30,000 VSAT's (Very Small Aperture Terminal satellites) In 2002, India had the largest telecom network in Asia, comprising 35,023 exchanges and around 45 million fixed-line telephones¹. The annual growth in the telecom industry is 7 %

Telemedicine: " Watson, come here I want you" said Alexander Graham Bell on March 20, 1876, when he

inadvertently spilled battery acid on himself, while making the world's first telephone call. Little did Bell realize that the first telephone call in the world was indeed the world's first tele medical consultation. We have come a long way since then.

Today using telemedicine, a patient can be examined, investigated, monitored and treated, with the patient and the doctor located in different places. The Greek word *tele* means "distance" and *mederi* is a Latin word meaning "to heal". In Telemedicine one transfers the expertise, not the patient. A major goal of telemedicine is to eliminate unnecessary travelling of patients and their escorts. Offering medical advice remotely, using state of the art telecommunication tools, is now a regular feature in several parts of the world. Several studies have shown telemedicine to be practical, safe and cost effective. Telemedicine hinges on transfer of text, reports, voice, images and video, between geographically separated locations Success relates to the efficiency and effectiveness of *image acquisition, image storage and transfer of information*. Using a PC, a scanner, a web/digital/video camera, appropriate software and telecommunications (ISDN lines, internet or VSAT) it is possible to transfer clinical data and carry out a reasonable clinical examination remotely.

In Utopia, every citizen has immediate access to the appropriate specialist for medical consultation. In the real world this cannot even be a dream. Incentives to entice specialists to practice in suburban and rural areas have failed. Worldwide there is difficulty in retaining specialists in non-urban areas. The increasing availability of excellent telecommunications, infrastructure and video conferencing equipment will help "provide" a physician where there was none before. Once the "virtual" presence

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of the specialist is acknowledged, a patient can access resources in a tertiary referral centre without the constraints of distance. This also ensures maximal utilisation of suburban hospitals. With modern software/hardware at either end 90% of the normal interaction can be accomplished through Telemedicine. Most head injury patients seeking specialist attention have to be accompanied by able bodied attenders. If the total man hours lost is added to transportation, boarding and lodging, the savings accrued through telemedicine is considerable.

The Indian Scenario: India has the unique advantage of being in the forefront of the information technology revolution. We no longer have to *follow* the advanced countries, we do not even have to *piggy back*, we can *leap frog!* Using appropriate need based technology, many head injuries can be properly managed remotely. Telemedicine is also an excellent CME medium educating the non specialist in the management of head trauma. Managing head injuries personally, with the confidence that a specialist is only a mouse click away, does wonders for a rural physician's morale. Using ISDN lines and VSAT satellites the author has helped family physicians in distant parts of India to manage simple and not so simple head injuries.

Literature reviewing the use of telemedicine in the delivery of health care in the Indian context is now available¹⁻¹². Indian literature on the specific use of telemedicine in neurosciences is limited¹³⁻¹⁷. It is generally assumed that communities most likely to benefit from telemedicine are those least likely to afford it or have the requisite communication infrastructure. This may no longer be true. Computer literacy is fast developing and computer prices are falling. Health care providers are now looking at Telemedicine to bridge the gap. Theoretically, it is easier to set up an excellent telecommunication infrastructure in suburban and rural India than to place hundreds of medical specialists in these places. The distribution of neurosurgeons in India is lopsided. Greater Chennai with a population of six million has 85 neurosurgeons, more than in all the states of North eastern India having a population of 250 million. Quite often, many patients are sent to far away tertiary centers, at considerable expense. In many of these cases, the treatment could have been carried out by the local doctor with advice from a specialist.

In a developing country where cost containment is the order of the day, one has to ponder over several issues. Will faster transmission of images or better image quality actually alter diagnosis or treatment? Is the most effective mode of data acquisition, compression, transfer

and manipulation at the tele consultant's console necessarily the most cost effective and does this alter management.

The Aragonda Story: The first modern secondary care, rural hospital using Telemedicine to provide expert care, set up by the Apollo group of hospitals was formally commissioned in March 2000 by the then president of the United States Bill Clinton. This village hospital in Aragonda (population 5000), is 16 km from the nearest large town Chittoor in the state of Andhra Pradesh. This 40 bedded hospital is equipped with a CT scan, a modern ultrasound, ECHO, automated laboratory equipment, an incubator, trans telephonic ECG etc. A paediatrician, a general physician and a general surgeon are available in addition to rotating interns. Starting from simple web cameras and ISDN telephone lines today the village hospital has a state of the art video conferencing system and a VSAT satellite installed by ISRO (Indian Space Research Organisation). In the last 48 months about 950 tele consultations have been given to this village, by specialists and super specialists from Chennai. A specially designed software is used and the clinical history and physical findings are transferred from the village of Aragonda. Images of x rays and ultrasound were scanned, compressed and initially sent through ISDN lines (64 x 6 384 kbps). CT images and Echocardiograms being DICOM compatible were directly electronically transferred to the telemedicine computer at Aragonda for onward transmission to Chennai. Since it was difficult to always ensure trouble free maintenance of sophisticated equipments in an isolated village, occasionally, hard copies of CT films were scanned and transmitted. The teleconsultations were initially off line – store and forward. The tele consultant's opinion was sent back to the primary physician. There were no fixed hours for tele consultation – a medical officer being available at the telemedicine unit at Chennai from 9am to 5pm. A hot line directly connected to the VSAT at either end is also available. Provision for emergency tele consultation is also available. When the tele consultant wanted to directly interact with the primary physician and the patient, a "net meeting" was initially arranged. Later on a formal video conference was held. All such on line interactions were recorded and stored. Detailed clinical "examination" was possible. More than 100 patients with various types of head trauma have been evaluated remotely. Video recordings of clinical examinations are stored.

Head injuries evaluated included concussions, post traumatic seizures, fissured fracture skull, depressed fracture skull, contusion brain, primary brain stem injury,

diffuse cerebral injury, acute, subacute and chronic subdural hematomas and extradural haematomas. Many of these cases had poly trauma. Transfer to a tertiary care hospital was advised in less than 10%. Fifteen patients initially treated at Chennai for major head injuries were re evaluated from Aragonda.

Tele Consultations Included : (a) discussing the strategy to be adopted in use of anti edema measures and prophylactic anticonvulsants in an unconscious young woman who was eight weeks pregnant. As this patient did not require surgery she was managed at the village hospital with guidance through teleconferencing. (b) medication to be administered to control an aggressive boisterous patient with non operable temporal lobe contusion, (c) when to institute prophylactic anticonvulsants, for how long etc. Most of the tele-referrals dealt with practical day to day problems. Giving advise to a doctor practising in a village setting, on how to treat head injuries often meant facing ground realities. Published literature, evidence based medicine and practise in state-of- the- art neuro trauma ICU's obviously could not be totally extrapolated !! Several grievous head injuries not requiring surgery were successfully managed in the village hospital. Five cases of head injuries were operated by the general surgeon (three cases of depressed fracture, one extradural haematoma and one acute SDH). This was made easier as the general surgeon had visual access to the neurosurgeon in Chennai. In almost all cases the tele consultant was able to give a definite opinion and guide the local physician. Details of the treatment were discussed in detail with the patient and the family. The family felt reassured that expert advise was being given to their primary physician. These tele discussions were of considerable help. Interestingly

the acceptance of tele consultation by the rural patient, the sub urban doctor and the suburban community was much better than expected. None of them were really averse to a tele consultation. The tele consultants have also accepted this new method of interacting with a patient. Detailed evaluation of the socio economic benefits needs to be done.

The Sriharikota Story: Sriharikota Space Center is an important launch pad of the Indian Space Research Organisation located 130 kms from Chennai. The Health Center also provides medical assistance to the neighbouring villages. A virtual OP is operational every Saturday from 10am to 1pm at Chennai. 25 different specialities are covered, some every week, others once a fortnight and others once a month. A hot line directly connected to the VSAT at either end is also available. Provision has been made for emergency neurosurgical tele consultations. About 15 cases of minor head trauma have been managed remotely.

Apollo Telemedicine centres are now operational at Agartala, Ahmedabad, Aragonda, Bachel, Bangalore, Bangladesh, Bilaspur, Bhubaneshwar, Burdwan, Chennai, Colombo, Cuddapah, Delhi, Dibrugarh, Dimapur, Eluru, Gleanegals, Gurgaon, Guwahati, Howrah, Hyderabad, Jamshedpur, Karim Nagar, Karthala, Kazakasthan, Kohima, Kolkata, Kota, Madurai, Mysore, Port Blair, Pudukottai, Raichur, Satna, Silchar, Siliguri, Srihari, Srinagar, Tinsukia, Tondairpet. The tertiary care Apollo hospitals at Delhi, Hyderabad and Madurai are interconnected. Many other peripheral centers are to be commissioned soon. Neurosurgical opinion is occasionally sought for subacute, chronic and minor head injuries, from these centers. Most of the cases could be managed at these small centres by the local physician.

The Global Scenario: Worldwide the number of neurosurgeons available to manage head trauma is sub optimal. Gray has reviewed the benefits and pitfalls of telemedicine in neurosurgery¹⁸. Previous publications where telemedicine has been used in the remote management of head trauma has shown that unnecessary transfers are reduced¹⁹ reducing the work load on increasingly stretched hospital and ambulance services²⁰. More therapeutic measures are implemented *before* transfer, when the investigations done can actually be seen and the patient "examined". Transfer time is shortened and safer^{21,22}. With increasing deployment of telemedicine facilities several questions are being raised. Is regionalization of trauma care using telemedicine feasible and desirable²³? Is telemedicine useful in an

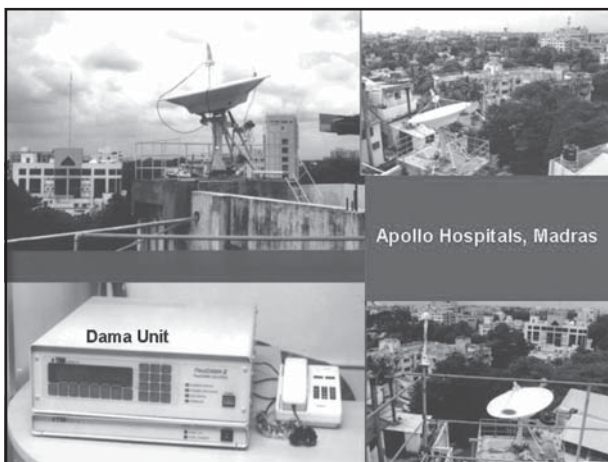


FIGURE 1. VSAT at Apollo Hospitals, Chennai.

accident and emergency setting^{24,25}? Can the quality of information provided in telephoned head injury referrals be improved²⁶? Can nurses evaluate and manage traumatic brain injury on the telephone²⁷? Can a decision to transfer a patient to a neurosurgical unit be based solely on a voice telephone call ?

Community based care following traumatic brain injury using telehealth is now a reality²⁸. Trauma debriefing by telemedicine has also been reported²⁹. Follow up of head trauma through tele consultations has confirmed its usefulness³⁰. Gray's reports³¹⁻³³ on the national neurosurgical tele radiology system in Ireland, is an example of how tele consultation can considerably extend the reach of a small number of neurosurgeons. The system connected six major referring hospitals to the only two neurosurgical departments serving the entire population of 3.5 million people. The system was based on Personal Computer's interconnected by leased data circuits and ISDN lines. The network operational 24 hours a day, was user friendly and reliable. Over 750 emergency computerized tomography scans were transmitted and transmission failures occurred in only 6%. The authors pointed out that because of the widespread installation of CT scanners in peripheral hospitals, scans were obtained before referral to a neurosurgical center. A significant change in management occurred in 55 of 68 cases (81%), principally as a result of prevention of transfer of head-injured patients. when no neurosurgically correctable lesion was evident³⁴. In most cases the CT and MRI scanners could not be "upgraded" to be DICOM compatible. This necessitated the use of hard copies for scanning. Scanning was also beneficial for transmission of lateral cervical spine films and chest films. High quality of transferred images resulted in appropriate specialist advice to generalists in district hospitals³⁴.

Cost implications of out-patient teleneurology³⁵⁻³⁷ applications of the World Wide Web and the internet, to neurosurgical practice^{38,39} have been discussed but not with specific reference to head injuries. The necessity for evaluation of telemedicine in an Accident and Emergency setting including a cost-benefit analysis has been stressed by Beach et al⁴⁰. Time taken for transmission of images in tele consultation is crucial. Image selection has been proposed as a useful strategy⁴¹. Urban⁴² proposed a new neurosurgical image transfer system for routine and emergency cases. A hand-held, inexpensive digital camera may be an alternative to expensive, labor-intensive teleradiology systems⁴³. It can be considered as an option for small community-based

hospitals unable to support more sophisticated teleradiology techniques. ATM (Asynchronous Transfer Mode). is also an efficient technology for fast transfer of radiological examinations in DICOM format and for discussions through high-quality videoconferencing. It can be used in lieu of N-ISDN (Narrowband Integrated Service/Digital Network for the inter-hospital management of neurosurgical patients⁴⁴.

*Brain surgery by fax*⁴⁵ is the provocative title given to a publication where telecommunications was used in a rural emergency. Simpson⁴⁶ in a provocative article discusses how neurotrauma without neurosurgeons may be a reality. Evaluation of clinical data by remote observation in trauma has also been studied^{47,48}. Craig has demonstrated that neurological examination using telemedicine is at least as good as face-to-face examination performed by a junior doctor⁴⁹.

In one study four community hospital emergency departments in upstate New York and Vermont were equipped with dual cameras with remote control capability. Three trauma surgeons' homes were wired and equipped with telemedicine systems. Telemedicine enabled a virtual online trauma surgeon to assist with the resuscitation and stabilization of major trauma patients in small community hospitals⁵⁰. Boulanger et al⁵¹ showed that telemedicine-based follow up of trauma patients discharged to remote areas in the Kentucky region in the USA is feasible and is associated with high patient and physician satisfaction⁵¹. Rehabilitation of seriously injured head trauma patients can also be achieved through telemedicine⁵².

The judgement and skill of an experienced surgeon are crucial ingredients during trauma resuscitation, so



FIGURE 2. Tele-evaluation of Peripheral Nerve Injury.

that errors of omission, commission, and mis-prioritization can be avoided. Remote evaluation of trauma victims is feasible⁵³. Accurate clinical data can be recorded, tasks delegated, and therapeutic measures advised using telemedicine. This can make expert trauma care available to hospitals without advanced trauma systems and potentially reduce cost, prevent unnecessary transfers, and promote early transfer when indicated⁵⁴. Viewing radiographs of acutely injured trauma patients can influence many aspects of management of inter hospital transfer⁵⁵. Worldwide head injuries still constitute a small portion of teleconsults even in trauma. Lambrecht reviewing 100 teleconsultations concerning trauma noted that 54 trauma teleconsults were provided by orthopedic surgeons, Emergency physicians provided 33, Radiologists 8, and Neurosurgeons provided five teleconsultations⁵⁶.

In a study concentrating on quality of image transmission in Bavaria the authors concluded that in 95% of trauma cases the transmitted material was at least sufficient to take a decision⁵⁷. With increasing availability of CT scanners in peripheral hospitals immediate CT scanning is possible, and this can lead to early diagnosis and referral of head injuries. However, neurosurgical services in most countries remains regional with limited bed capacity. Inter-hospital transfer of critically ill patients may be potentially hazardous. Eljamel investigated the value and reliability of telemedicine in the management of emergency neurosurgical referrals. 199 emergency referrals were studied. In 147 the patient was scanned in the referring hospital and the images transmitted immediately to the neurosurgical unit. Of these, 51 (34.7%) patients were transferred immediately, 14 (9.5%) the following day and 11 (7.5%) electively. Of those patients who were transferred immediately, 48 (94.1%) underwent emergency surgery.. Image transfer together with clinical history reduced potentially hazardous inter-hospital transfer of patients ($p < 0.001$). It is reliable, fast, inexpensive and leads to considerable economic savings⁵⁸.

The Future

The potential influence of telemedicine in the care of trauma patients may alter patterns of referral, consultation, and treatment⁵⁹. CT images of head trauma can now be received on a pocket computer via a wireless modem link. Quality of the images are satisfactory. Reliability in obtaining a wireless internet connection is good, but not perfect. Wireless pocket telemedicine devices carried by neurosurgeons will further facilitate real time diagnosis of head trauma patients when a specialist is not available^{60,61}.

CONCLUSION

The first generation of telemedicine enthusiasts should not forget that technology should be used as a support to treat patients, not viewed as a goal in itself. The challenge today is not confined to overcoming technological barriers, insurmountable though they may appear. It is true that available technology still has considerable scope for improvement. Rather the challenge is why, where and how, to implement which technology and at what cost. A needs assessment is critical. The take off problems, facing telemedicine is legion. Telemedicine today sounds hep and cool, but the reality may be quite different. The future however promises to be exciting. The journey will well be worth the wait.

The preliminary results of what started as a concept validation pilot project, using telemedicine for rural India may revolutionise the delivery of health care in India and hopefully in other developing countries as well. An interesting by product of teleconsultation has been the drop in neurosurgical tele referrals from the rural centers which have access to telemedicine facilities. The doctor at the remote centre has acquired the confidence to manage most cases of head trauma. In a general, community hospital setting, less than 10% of head injuries require surgery or referral to neuro intensive care units. In the past, the family physician did not have the skills to manage head injuries or simple poly trauma cases. With immediate access to specialists in tertiary



FIGURE 3. Tele- examination of pupillary reaction

care centres through telemedicine, this is no longer true.

It is the author's dream that eventually there will be telemedicine kiosks in suburban and rural India. No Indian should be deprived of a specialist consultation wherever he/she is. This is not impossible. What is

required is not implementing better technology and getting funds but changing the mind set of the people involved to ensure that specialist consultation is only a mouse click away!

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REFERENCES

1. Sood, S. (2003). *Bringing medicine to India's masses*. [Available from the World Wide Web: <http://www.hospitalmanagement.net>
2. Ganapathy K. Abstracts of First International Conference of Telemedicine in India (Telemed 2000) Special lecture on "A Clinician's perspective of Telemedicine" and "Strategies for Introducing Telemedicine in India"
3. Ganapathy K. Abstracts of proceedings of the First International conference on Arab Telemedicine January 2001 Cairo "Telemedicine in India"
4. Ganapathy K. Abstracts of "Telemedicine in Action – The Apollo experience" at the International Conference on Medical informatics November 23rd 2001 Hyderabad
5. Ganapathy K: Telemedicine www.expresshealth-caregmt.com
6. Ganapathy K : Proceedings of ICRAN 2002 (International Congress of Recent Advances in Neuro traumatology) <http://www.monduzzi.com/proceedings> <http://www.telemedicine.lu/eng/chap09/c0903a.htm>
7. Ganapathy K. Telemedicine in action <http://www.thamburaj.com>
8. Apollo Hospitals (2003) *Telemedicine in Chennai*. Available from the World Wide Web: <http://www.apollohospitals.com>
9. Dutta, R. (2003). *Telemedicine: Is it in anyway beneficial for 620 million rural Indian?* Available from the World Wide Web: <http://www.expresshealthcaregmt.com>
10. Times of India (2001). *Telemedicine now in rural pockets of western India*. [Online]. Available from the World Wide Web: <http://www.indiatimes.com>
11. Ganapathy K : "Country – India" In, Andrew Steele (Ed). *Medical Informatics Around The World: An International Perspective Focusing On Training Issues*. Universal Publishers/uPUBLISH.com (2002)1581126344: pp 57-65.
12. Ganapathy K: Relevance of telemedicine in caring for the less than abled. p 137 -139. Report of the Conference on Information Technology Enablers for persons with Disability. Institution of Electronics and Telecommunications Engineers 2001
13. Ganapathy.K. Abstracts of Media Lab Asia – Asian Regional Network Conference – April 25, 2002 at New Delhi – "Digital Village: Towards a Sustainable Future" talk on "Telemedicine-fact or fiction"
14. Ganapathy.K. Abstracts of "Telemedicine and Neurosciences A historical perspective of the global and Indian scenario" Golden jubilee conference of the Neurological Society of India December 2001
15. Ganapathy.K. "Telemedicine and Neurosciences" *Progress in Clinical Neurosciences* 2002; 17, 1-10,
16. Ganapathy.K Telemedicine and Neurosciences in developing countries. *Surgical Neurology* 2002; 58, 388-395.
17. Ganapathy.K. (under publication) Abstracts of proceedings of The First Intensive Balkan Telemedicine Seminar Prishtina, Kosova: Telemedicine and Telehealth in Developing Countries: October 2002. Paper on "Telemedicine and Neurosciences"
18. Gray W, O'Brien D, Taleb F, Marks C, Buckley T: Benefits and pitfalls of telemedicine in neurosurgery. *J Telemed Telecare* 1997; 3: 108-10.
19. Servadei F, Antonelli V, Mastrilli A, Cultrera F, Giuffrida M, Staffa G. Integration of image transmission into a protocol for head injury management: a preliminary report. *Br J Neurosurg* 2002;16:36-42
20. Lee T, Latham J, Kerr RS, et al. Effect of a new computed tomographic image transfer system on management of referrals to a regional neurosurgical service. *Lancet* 1990; 336:101-3
21. Goh KY, Lam CK, Poon WS: The impact of teleradiology on the inter-hospital transfer of neurosurgical patients. *Br J Neurosurg* 1997; 11:52-56
22. Goh KY, Tsang KY, Poon WS: Does teleradiology improve inter-hospital management of -injury? *Can J Neurol Sci* 1997; 24: 235-9
23. Aucar J, Granchi T, LiscumK, Wall M, Mattox K: Is regionalization of trauma care using telemedicine feasible and desirable? *Am J Surg* 2000;180; 535-9
24. Beach M, Miller P, Goodall I: Evaluating telemedicine in an accident and emergency setting. *Comput Methods Programs Biomed* 2001;64; 215-23
25. Smith RS: Telemedicine and trauma care. *South Med J* 2001;8; 825-9
26. Walters KA. Telephoned head injury referrals: the need to improve the quality of information provided. *Arch Emerg Med* 1993; 10: 29-34.
27. Martin EM, Coyle MK, Warden DL, Salazar A. Telephonic nursing in traumatic brain injury. *Am J Nurs*. 2003;103:75-81.
28. Schopp L. Telehealth and traumatic brain injury: creative community-based care. *Telemed Today* 2000;8 :4-6.
29. Yellowlees P. Trauma debriefing by telemedicine. *J Telemed Telecare* 1998;4:239-40
30. Tachakra S, Loane M, Uche CU: A follow up study of remote trauma teleconsultations. *J Telemed Telecare* 2000;6; 330-4
31. Gray WP, Somers J, Buckley TF: Report of a national neurosurgical emergency teleconsulting system. *Neurosurgery* 1998 42:103-108,
32. Gray WP, Somers J, Buckley TF: Report of a national neurosurgical teleradiology system. *J Telemed Telecare* 1997;3; 36-7

33. Gray WP: Report of a national neurosurgical teleradiology system based on optical scanning technology. Proceedings of the 9th European Congress of Radiology. *Eur Radiol* 1995 ;5:296.
34. Spencer JA, Dobson D, Hoare M, Molyneux AJ, Anslow PL: The use of a computerized image transfer system linking a regional neuroradiology center to its district hospitals. *Clin Radiol* 1991; 44: 342-344.
35. Chua R, Craig J, Wootton R, Patterson V: Cost implications of out-patient teleneurology. *J Telemed Telecare* 2001;1: 62-64
36. Bailes JE, Poole CC, Hutchison W, Maroon JC, Fukushima T: Utilisation and cost savings of a wide area computer network for neurosurgical consultation. *J Telemed Telecare* 1997; 3: 135-9.
37. Maass M, Kosonen M, Korman M: Transportation savings and medical benefits of a tele neuro radiological network. *J Telemed Telecare* 2000; 6: 142-6.
38. Fujimaki T: Applications of the World Wide Web to neurosurgical practice. *Neurosurgery* 1997 ; 41: 995-6.
39. Pareras LG, Martin-Rodriguez JG: Neurosurgery and the Internet: a critical analysis and a review of available resources. *Neurosurgery* 1996 ; 39: 216-32
40. Beach M, Miller P, Goodall I: Evaluating telemedicine in an accident and emergency setting. *Comput Methods Programs Biomed* 2001;64; 215-23
41. Ludwig K, Bick U, Oelerich M, Schuierer G, Puskas Z, Nicolas K, Koch A, Lenzen H :Is image selection a useful strategy to decrease the transmission time in teleradiology? A study using 100 emergency cranial CTs. *Eur Radiol* 1998; 8:1719-21
42. Urban V, Busart C, Huwel N, Perneezky A: Teleconsultation: A new neurosurgical image transfer system for daily routine and emergency cases—a four year study. *Eur J Emerg Med* 1996; 3: 5-8.
43. Sherry L Apple, John H Schmidt : Technique for neurosurgically relevant CT image transfers using inexpensive Video Digital Technology. *Surg Neurol* 2000; 53: 411-16.
44. Heautot JF, Gibaud B, Catroux B, Thoreux PH, Cordonnier E, Scarabin JM, Carsin M, Gandon Y: Influence of teleradiology technology (N-ISDN and ATM) on the inter-hospital management of neurosurgical patients. *Med Inform Internet Med* 1999; 24: 121-34
45. Rottger J, Irving AM, Broere J, Tranmer B: Use of telecommunications in a rural emergency. Brain surgery by fax. *J Telemed Telecare* 1997; 3: 59-60.
46. Simpson D.Neurotrauma without neurosurgeons? *Aust N Z J Surg* 1994;64:525-6
47. Lambrecht CJ. Telemedicine in trauma care. *Telemed Today* 1998;6:25
48. Aucar JA, Villavicencio RT, Wall MJ Jr, Liscum KR, Granchi TS, Mattox KL Evaluation of clinical data by remote observation in trauma. *Proc AMIA Annual Fall Symp* 1997;;408-12
49. Craig JJ, McConville JP, Patterson VH, Wootton R: Neurological examination is possible using telemedicine. *J Telemed Telecare* 1999; 5: 177-81.
50. Rogers FB, Ricci M, Caputo M, Shackford S, Sartorelli K, Callas P, Dewell J, Daye S. The use of telemedicine for real-time video consultation between trauma center and community hospital in a rural setting improves early trauma care: preliminary results. *J Trauma* 2001;51:1037-41
51. Boulanger B, Kearney P, Ochoa J, Tsuei B, Sands F .Telemedicine: a solution to the followup of rural trauma patients? *J Am Coll Surg* 2001;192:447-52
52. Ricker JH, Rosenthal M, Garay E, DeLuca J, Germain A, Abraham-Fuchs K, Schmidt KU. Telerehabilitation needs: a survey of persons with acquired brain injury. *J Head Trauma Rehabil* 2002 ;17:242-50
53. Tachakra S, Jaye P, Bak J, Hayes J, Sivakumar A. Supervising trauma life support by telemedicine. *J Telemed Telecare* 2000;6 Suppl 1:S7-11
54. Aucar J, Granchi T, Liscum K, Wall M, Mattox K. Is regionalization of trauma care using telemedicine feasible and desirable? *Am J Surg* 2000;180:535-9
55. Kirkpatrick AW, Brennehan FD, McCallum A, Breeck K, Boulanger BR. Prospective evaluation of the potential role of teleradiology in acute inter hospital trauma referrals. *J Trauma* 1999;46:1017-23
56. Lambrecht CJ. Telemedicine in trauma care: description of 100 trauma teleconsults. *Telemed J* 1997 Winter;3(4):265-8
57. Stieglitz SP, Gnann W, Schachinger U, Maghsudi M, Nerlich M.Telecommunication in trauma surgery. Communication networks of hospitals in East Bavaria. *Chirurg* 1998; 69 :1123-8
58. Eljamel MS, Nixon T: The use of a computer-based image link system to assist inter- hospital referrals. *Br J Neurosurg* 1992; 6:559-62
59. Smith RS.Telemedicine and trauma care. *South Med J* 2001;94:825-9
60. Yamamoto LG, Williams DR: A demonstration of instant pocket wireless CT teleradiology to facilitate neurosurgical consultation and future telemedicine implications. *Am J Emerg Med* 2000 ; 18: 423-6.
61. Mikito Yamada, Hirota Watarai, Takashi Andou, Noboru Sakai .Emergency Image Transfer System through a Mobile Telephone in Japan: Technical Note *Neurosurgery* 2003; 52: 986-990.