Teleoncology: current and future applications for improving cancer care globally

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Access to quality cancer care is often unavailable in low-income and middle-income countries, and also in rural or remote areas of high-income countries. Teleoncology—oncology applications of medical telecommunications, including pathology, radiology, and other related disciplines—has the potential to enhance access to and quality of clinical cancer care, and to improve education and training. Implementation of teleoncology in the developing world requires an approach tailored to priorities, resources, and needs. Teleoncology can best achieve its proposed goals through consistent and long-term application. We review teleoncology initiatives that have the potential to decrease cancer-care inequality between resource-poor and resource-rich institutions and offer guidelines for the development of teleoncology programmes in low-income and middle-income countries.

Cancer care disparity: a global problem

There are gaps in cancer care globally. The inadequacies in low-income and middle-income countries (LMCs) are most widely recognised. WHO recently reported that further economic development in LMCs is hindered by the substantial burden of morbidity and mortality from chronic diseases.[1] An estimated 80% of chronic disease deaths occur in LMCs,[1,2] which lose more lives each year to cancer than to AIDS.[2] National economic status is an important factor in access to modern cancer care. The World Bank classifies nations by gross annual per-capita income as low-income countries (LIC; US$935 or less), middle-income countries (MIC; $936–11 455), and high-income countries (HIC; $11 456 or more). MICs are further divided into lower ($936–3705) and upper ($3706–11 455) MICs.

The global incidence of cancer is projected to increase by 50% over the next 20 years,[3] and most cases will occur in LMCs,[2] which have only 5% of the world's resources. Cancer is the second most common cause of death in children in many Latin American countries,[4] although as many as 70% of paediatric cancers are curable with appropriate diagnosis and treatment.[5] Disparities in cancer care are also present in HICs, usually involving the unavailability of specific specialties, diagnostic facilities, and treatment infrastructure in remote or rural areas.[6] These disparities are likely to increase; in the USA, a shortage of about 3800 oncologists is projected by the year 2020.[7]

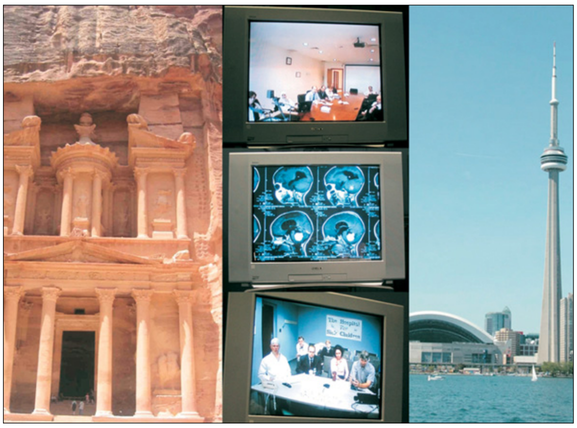

Figure 1: **Teleoncology links ancient and new worlds**
A monthly videoconference allows the neuro-oncology teams of King Hussein Cancer Center (Amman, Jordan) and Hospital for Sick Children (Toronto, Canada) to view and discuss complex brain tumour cases .

The potential of teleoncology

Systematic and effective communication between advanced oncology centres and remote or resource-poor centres can improve cancer care and enhance opportunities for continuing clinical education. Therefore, disparities in cancer care can be reduced by the development of resources—staff and telecommunication infrastructure—that link institutions with different levels of funding and expertise (figure 1).

Telemedicine has various definitions, but the ones used by WHO, the European Commission, and the American Telemedicine Association emphasise the use of telecommunication to advance health. Teleoncology is the application of telemedicine to oncology, including diagnostics (laboratory, radiology, pathology), treatment (surgery, radiation oncology, medical oncology), and supportive care (rehabilitation and palliative). Therefore, teleoncology includes any telemedicine application used to advance cancer care.[8] Data derived from telemedicine in general will be provided where it informs potential teleoncology efforts.

Telecommunication technologies

Several communication technologies can support effective teleoncology. Synchronous (real-time) interactive videoconferencing is one of most common.[9] A fully equipped videoconferencing unit with six integrated-services digital network (ISDN) transmission channels (384 kb/s) is costly and requires technical support that is not available in many LMCs.[9] However, more affordable systems may be feasible. In Ecuador, a videoconference unit using a modem for transmission (56 kb/s) was recently installed for less than US$1000,[10] although it has not been assessed for teleoncology applications.

Many collaborative internet protocols that allow synchronous interaction among participants have recently emerged. Some of these, collectively termed web conferencing protocols, are very robust and support voice and visual teaching applications. The main advantages of these systems are their low cost and minimal technical maintenance requirements (table 1). A web conferencing initiative hosted by the St Jude Children's Research Hospital site Cure4Kids has been successfully used for 6 years to support the hospital's International Outreach Program (IOP) partners.[11] The high-end synchronous systems, such as telesynergy systems,[12] robotic telesurgery,[13] and virtual microscopy,[14] are likely to be used only in resource-rich countries. Because they can transmit high-resolution images for clinical, pathological, and radiological diagnosis, many hospitals in the USA and Europe use these systems to overcome lack of local expertise.

Asynchronous interaction, also known as the store-and-forward method, uses software to transmit, store, and retrieve data or digital images.[15] Store-and-forward communication is practical for specialties that require imaging. For example, the non-profit organisation, ORBIS, links clinicians in developing countries with mentors in developed countries to improve the diagnosis and management of ocular diseases, including cancer.[16] Retinal images obtained via fundus or retinal camera can be uploaded to the ORBIS site, which also supports related magnetic resonance, CT, and ultrasound images, allowing full consideration of specific case details by the mentor (figure 2). Telepathology frequently uses store-and-forward methods.[17] One of the earliest non-real time telemedicine initiatives, SatelLife, began in 1991 and continues to support e-mail consultations, teleconferencing, and online educational content via a low-orbit satellite.[18] Finally, e-mail is a widely used but under-reported method of teleoncology.[19,20]

	Advantages	Disadvantages
Web conferencing	Low cost Wide availability	Limited resolution of images Images cannot be manipulated Participants might not see each other*
Video-conferencing	Good image resolution Images can be manipulated Participants can see each other Readily available Can present/interview patients Supports image-intensive clinical case collaborations (diagnosis, radiation/surgery planning, disease monitoring)	Expensive Requires maintenance
Telesynergy®	A multimedia workstation integrates all components for collaborative multidisciplinary teleoncology High image resolution Transmits images from their primary sources Allows image manipulation Supports comprehensive multidisciplinary case review and discussion Supports collaborative planning of radiation and surgery	Very expensive Requires about 20 ISDN channels Requires many peripheral components Difficult to install Requires intensive maintenance Requires dedicated storage space
Virtual telemicroscope	Operator can control microscope without special hardware or software Good image resolution	Limited to pathology Expensive Performance depends on the user's computer
Robotic telesurgery	Circumvents hand tremors Supports fine surgical movements	Bulky equipment Very expensive Requires special training

ISDN=integrated-services digital network. *A substantial increase in bandwidth and expense would be required.

Table 1: **Advantages and disadvantages of synchronous technologies applicable to teleoncology**

Teleoncology in high-income countries

Improvement of outcomes in underserved areas and dispersed populations

The regions and countries of Europe are heterogeneous in their resources, populations, and needs, and cancer outcomes can vary accordingly.[21] Table 2 provides several examples of successful teleoncology initiatives at the continental or national level. The Clinical Oncology Network for Quality in European Standards of Treatment (CONQUEST)[21] was launched in response to widely disparate rates of breast-cancer recurrence at European hospitals (10·5%–36% after breast-conserving therapy and 4·6%–21·3% after mastectomy).[37] Another continent-wide project is the Trans-European Network for Positron Emission Tomography (TENPET), which supports teleconsultation for the performance and interpretation of PET scans.[22] The International Union Against Cancer's Telepathology Consultation Center[17] and the i-Path[24] system are widely used to support pathology consultation in Europe. At the national level, Norway[25] became the first country to reimburse providers for telemedicine services in 1996.[38] Scotland[26] and Germany[27] have implemented teleoncology systems for treatment planning for breast cancer and Hodgkin's lymphoma, respectively.

For more on **Cure4Kids** see www.cure4kids.org

For more on the **ORBIS organisation** see www.orbis.org

Like Europe, the USA has underserved populations and cancer outcomes are worse in rural or remote areas.[6,39] Onega and colleagues[6] proposed that specialty cancer care be delivered via teleoncology in the USA to decrease the travel burden and improve access. There are many successful and sustainable teleoncology initiatives in the USA, including cancer care for the widely dispersed US military population[28] and a well known teleoncology application developed by the University of Kansas Medical Center to serve its large rural patient base (table 2).[29,30] Gaps in care are greater in rare oncology subspecialties such as cancer genetics.[31]

Japan's teleoncology cancer centre network[32] conducts around 130 teleconferences each year, attended by 16 000 people, and hosts regular telepathology and teleradiology meetings. A programme developed by WHO to meet the surging need for oncology care after the Chernobyl catastrophe[33] links Nagasaki University to two hospitals in Belarus and Kazakhstan.[34] Both New Zealand[35] and Australia[36] have active teleoncology services for skin cancer (table 2).

Improvement of outcome in clinical trials

The negative effect of errors in diagnosis,[40] staging,[41] and treatment delivery[42] is well documented by retrospective

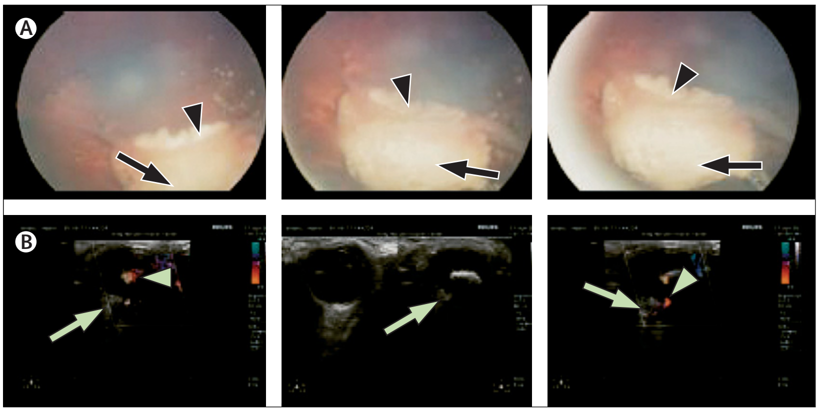

Figure 2: **Presurgical ocular teleoncology consultation**
The right eye of a patient after chemotherapy for a complex case of bilateral retinoblastoma treated in Jordan. In A, retinal photographs show tumour (arrows) and retinal folds (arrowheads). In B, doppler ultrasound images show tumour (arrows) and active blood flow (arrowheads). All ocular cancer cases at the Jordanian centre were discussed with the mentoring team at St Jude Children's Research Hospital before major intervention. Because blood flow suggested a viable tumour, enucleation was initially considered, but the mentoring team recommended observation, since blood flow appeared to be localised in the retinal fold. Although the left eye required enucleation, the right eye was salvaged and the young patient retained vision.

studies. For example, 30% of patients diagnosed with high-grade glioma were subsequently found to have had low-grade glioma.[40] These patients underwent unnecessarily aggressive therapy that could have been prevented by protocol-directed prospective (ie, before treatment) telepathology review. Packer and co-workers[41] found, at the end of a medulloblastoma study, that patients who had received inadequate radiological staging were less likely to survive. Donaldson and colleagues[42] found that 5-year local control in patients with Ewing's sarcoma was 80% with the correct dose and volume of radiotherapy; however, in the same cohort, patients with minor and major treatment deviations had 5-year local control rates of only 48% and 16%, respectively. Rapidly received expert opinions at the time of staging and treatment planning can improve patient outcomes, improve the integrity of clinical trials data, and build the expertise of local cancer teams.

Teleoncology in LMCs

Limiting factors

Teleoncology is less available in LMCs than elsewhere. However, internet access is now readily available in all major cities of Africa,[43] and wireless high-speed internet service (using less costly medium-orbit satellites) is being introduced in LMCs by commercial providers. Desktop computers can be purchased for less than US$200, and laptops with wireless connectivity have been produced for less than $100 by the nonprofit organisation One Laptop Per Child. China and India have almost 37% of the world's population, have their own space programmes and high-speed internet service, and manufacture all equipment required for teleoncology. However, despite these resources, official telemedicine activity began in China only in 1995.[44] We believe that human factors, rather than lack of resources and technology, are often the main obstacle to teleoncology in LMCs.[45] As Ganapathy said, "what is required is not implementing better technology and getting funds, but changing the mindset of the people involved".[46] In China, a recent proliferation of telemedicine units has not been matched by a similar increase in human resources, leaving many such units underutilised.[47] In India, a fully equipped videoconference connection was established to help neurology specialists at two centres 1500 kilometers apart (the whole country has only 750 neurology specialists).[48] Over a 4-year period only 22 successful sessions were held.[48]

In many LMCs,[45] conflicts over professional and political power, fear of change, reluctance to seek a second opinion, and other human factors have obstructed the optimum use of teleoncology.

Successful initiatives

There have been several successful teleoncology initiatives in LMCs, although more are needed. India has one of the largest telemedicine operations in the developing world, with participation by both private and public sectors.[2,46,48,50] Other initiatives in Cambodia,[49] Solomon Islands,[24] Brazil,[51] and Jordan[9,16,20] are summarised in table 3.

The Cure4Kids website is an excellent example of a sustained teleoncology service that links providers in LMCs with experts in HICs.[11] The site regularly hosts synchronous discussions of specific diseases,[52] data management,[53] and other oncology issues[54] by staff at St Jude and its partner sites. More than 4000 oncology professionals attended online live meetings hosted by Cure4Kids from 2002 through 2008.[55] The site also offers multilingual educational material and a paediatric oncology nursing course—all of which have been extensively accessed.[55] The site was created by the St Jude IOP, established in 1994 to improve worldwide survival of children with catastrophic illness through the transfer of knowledge, technology, and organisational skills.[56] A detailed analysis of success factors during the first decade of IOP experience revealed the importance of sustained efforts and an emphasis on the human factor.[52,56]

Teleoncology in retinoblastoma—through ORBIS, Cure4kids, videoconferencing, or e-mail—was a major component in IOP initiatives in Central America[52] and Jordan.[16] Such long-term involvement with the partner sites helped to build trust and contributed to the change in mind set that facilitated the rapid acceptance of teleoncology.

Finally, teleoncology experiences reported in languages other than English[57] or in publications not available through PubMed may be underrepresented here. For example, the Mexican National Center for Health Technology Excellence provides detailed guidelines in Spanish for use of the Mexican telemedicine programme (which includes teleoncology).

For more on the **Mexican National Center for Health Technology Excellence** see www.cenetec.salud.gob.mx

Linking institutions in HICs and LMCs

LMCs are heterogeneous in their needs, communication infrastructure, and resources. Teleoncology programmes that are customised to these features have the greatest potential to improve cancer care. The following guidelines can help in the planning of teleoncology initiatives in such countries.

Focus on the human factor

There is little information available about the attributes necessary to ensure success and sustainability of telemedicine programmes,[58,59] although human factors have been identified, which suggest that a successful programme must have grass-roots, bottom-up support.[58] Available reports also stress that clinicians, not politicians, should be the decision makers and that efforts should focus on solutions to current health problems.[58,59] Otherwise, telecommunications equipment might be purchased and unused because of political conflict, competing priorities, or miscommunication.[59] Clinicians must be trained to use the equipment[58] and local technical staff instructed in antivirus software and equipment maintenance.[60] A study comparing telemedicine in the private and public sectors in India found that the private sector is more successful in improving clinical medical services.[24] The investigators attributed this finding to the needs-based approach of the private sector compared with the top-down approach characteristic of public programmes.

Build on twinning programmes

Teleoncology enhances and builds on established programmes. Teleoncology initiatives in LMCs often work best in the context of twinning programmes, or linking of existing local cancer centres with centers in HICs.[61] So far, evidence suggests that twinning improves cancer survival in LMCs,[52,56,62,63] and the integration of teleoncology into twinning programmes maximises clinical benefits and the effective use of resources.[16,19,52] To ensure broader benefits, the partner sites in LMCs should be encouraged to establish local, regional, or national networks. Further, cooperation among many cancer centres within and between LICs and MICs should be promoted (figure 3). Such multitiered telemedicine projects have been suggested[3] or piloted[51,57,64] in LMCs, but have so far lacked the element of twinning with cancer centres in HICs.

Tailor the approach to the country and targeted diseases

The first principle of a successful teleoncology system is pragmatic selection of goals and methods on the basis of needs and resources rather than politics and publicity.[58] Therefore, teleoncology programmes in lower-MICs (eg, Jordan[9,16]) or upper-MICs (eg, South Africa[65]) cannot realistically be used as models for programmes in LICs (eg, Yemen or Nigeria). To ensure an optimum clinical cost–benefit ratio, the needs and available resources of a specific country should dictate the objectives and the approach used for teleoncology within that country. The cancers to be targeted must be chosen similarly, on the basis of need, existing infrastructure, resources, and the complexity of the required treatment. For example, it

	Service area	Specialty/Disease	Method/Technology	Goal(s)
CONQUEST[21]	Europe	Radiotherapy Oncology	Videoconference	Quality assurance Improve clinical trials Access to medical records
TENPET[22]	Europe	Radiology	Interactive Store and forward	PET quality assurance
UICC-TCC*[17]	Europe	Pathology	Web-based	Consultation
i-Path system*[23,24]	Europe	Pathology	Web and email-based	Consultation
Quality assurance for radiotherapy[25]	Norway	Radiotherapy	Videoconference	Discuss radiotherapy planning
TELEMAM trial[26]	Scotland	Breast cancer	Videoconference	Randomised trial†
TeleRT network[27]	Germany	Radiotherapy Lymphoma	Videoconference Store and forward	Centralised radiotherapy review Quality assurance Improve clinical trials Education
VISN service area 20[28]	US military (AK, ID, OR, WA)	Oncology	Videoconference	MDTB for dispersed populations Improve referrals
University of Kansas Medical Center[29,30]	US (rural KS)	Oncology Hospice	Videoconference	Serve rural populations
Cancer genetic counseling[31]	US (rural NC)	Genetic counseling	Videoconference	Serve rural areas
NCC network[32]	Japan	Oncology Radiology Pathology	Videoconference	MDTB Education
IPHECA[33,34]	Belarus, Kazakhstan	Thyroid cancer Radiology Cytology	Communication satellite	Assist affected populations
Teledermatology[35]	New Zealand	Skin cancer	Videoconference	Serve rural populations
Teledermatology[36]	Australia	Skin cancer	Email (digital images)	Serve rural populations

CONQUEST=Clinical Oncology Network for Quality in European Standards of Treatment. TENPET=Trans-European Network for Positron Emission Tomography. UICC-TCC=International Union Against Cancer Telepathology Consultation Center. RT=radiotherapy. VISN=Veterans Integrated Service Network. AK=Alaska. ID=Idaho. OR=Oregon. WA=Washington. MDTB=multidisciplinary tumor board. KS=Kansas. NC=North Carolina. NCC=National Cancer Center. IPHECA=International Program on the Health Effects of the Chernobyl Accident. *European-based telepathology initiatives that are also used widely in low to middle-income countries, especially in Asia and Africa. †A randomised trial of consultation in person vs via videoconference, showing no difference in clinical effectiveness.

Table 2: **Summary of teleoncology initiatives in high-income countries**

	Mentor	Specialty	Technology	Goal(s)
India	None*	Radiation oncology	Videoconference	Establish a three-tier radiation oncology network[3]
		Cancer detection, treatment, and pain relief	Videoconference	Decrease referrals[24] Education[24]
Cambodia	USA	Consultation	E-mail	Second opinion[49]
Solomon Islands	Europe (i-Path)	Pathology	E-mail	Second opinion[50]
Brazil	None*	Paediatric oncology	Videoconference	Establish a cancer network[51]
International (Cure4Kids)†	USA	Paediatric oncology	Web conferencing	Twinning[11] Specific diseases[52] Data management[53]
Jordan	Canada	Paediatric neuro-oncology	Videoconference E-mails	Second opinion[9] Build local expertise[20]
	USA	Paediatric ocular oncolgy	Web-based (Orbis)	Team structure[16]

*These initiatives are designed to link resource-rich with resource-poor institutions or for networking within each country and not for twinning with centres in high-income countries (HIC). †Cure4Kids is used to facilitate twinning and telemedicine between centres in HICs and low to middle-income countries.

Table 3: **Summary of teleoncology initiatives in low-income and middle-income countries**

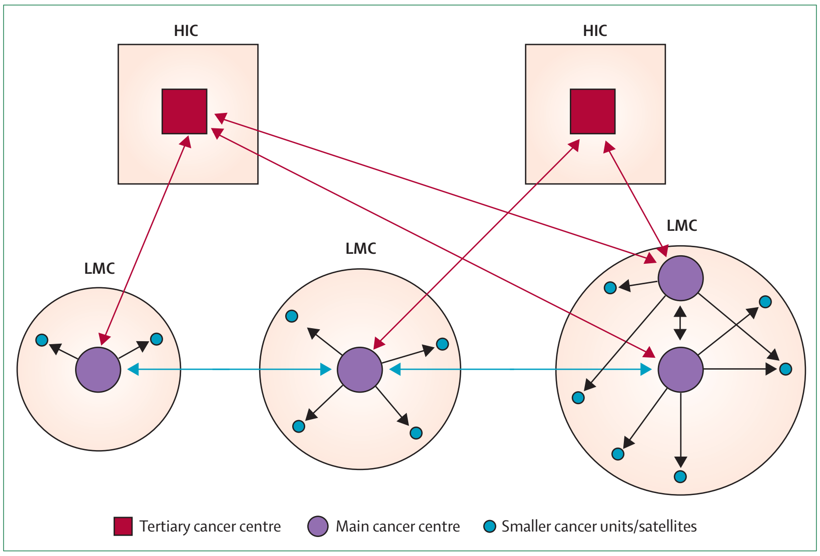

Figure 3: **Proposed multitiered collaborative teleoncology scheme linking cancer centres**
Teleoncology would be implemented at the international level between cancer centres in HICs and those in LMCs (red arrows) and between cancer centres in different LMCs (blue arrows). The scale of the programmes would depend on the population and number of cancer centres; a more extensive programme would be appropriate for a large LMC with more than one cancer centre. The level of technology used would depend on needs and resources. The main centres within each country would communicate with each other via advanced teleoncology, such as videoconferencing, and would mentor smaller cancer units using less expensive technology (black arrows). HIC=high-income country. LMC=low-income or middle-income country.

would be a misuse of resources for a country such as the Solomon Islands, which does not have a pathologist and whose internet bandwidth connections are limited,[50] to invest in videoconference units. Instead, this nation, with the help of cancer centres in HICs (Switzerland, Germany, and Australia) developed a practical, effective, and economical system that utilised an existing telepathology resource (iPath) based at Basel University (Switzerland). Further, an e-mail interface was added to overcome the limited internet connections in the Solomon Islands.

Involve allied health professionals

The lack of specialty physicians can hinder teleoncology initiatives in many LMCs. Nurses and other allied health professionals (technicians and medical and nursing students) can help to fill the gap by taking on additional training and responsibility. In both of the teleoncology initiatives in Jordan, the specialised nursing staffs of the neuro-oncology and ocular oncology services provided indispensable support, and their disease-specific skills greatly improved clinical care.[9,16,66]

In Brazil, a 150-min training session on melanoma allowed first-year medical students to accurately diagnose melanoma via a telemedicine model.[67] In another pilot project, a medical student from Emory University (Atlanta, GA, USA) spent 6 weeks in the Solomon Islands and had eight teleconsultations with his mentors after 1 hour of training with the system.[68] After the student departed, the local Solomon Islands team used this pilot telemedicine system to conduct 60 more teleconsultations.

Avoid sophisticated technologies

Advanced methods such as telesynergy,[12] virtual microscopy,[14] and robotic telesurgery[13] are unlikely to substantially improve health care in LMCs.[69] Expensive technologies often lead to the mismanagement of funds and may actually increase the gap in cancer care if access is available only to the wealthy.[69] As the costs of these approaches decrease in the future, they may become more accessible; however, in general they should be discouraged if they do not offer a clear benefit. Less expensive options, as discussed above, should be selected as appropriate for local needs and resources.

Expensive technologies that offer a clear advantage, such as videoconferencing, may already be in use for other purposes in LMCs. Existing equipment and resources should be explored as an alternative to purchasing new units for teleoncology. For example, the non-governmental organisation Medical Missions for Children, with support from commercial corporations, has established active videoconferencing capabilities for paediatric units in 58 LMCs.[70] In addition, many banks and other institutions in HICs and LMCs acquire videoconference units to unify their organisations and expedite communication. Such institutions may lend their units to local health-care providers for a few hours a month as a goodwill or public-relations gesture. Finally, many private hospitals in LMCs (as in India[24]) own telemedicine units that could be used for health care in the public sector if appropriate cooperation is established.

Other applications of teleoncology in LMCs

Linking resource-rich and resource-poor institutions

Many large LMCs, such as India, China, Russia, and Brazil, have tertiary cancer centres in their major cities that can serve as regional hubs for extending resources and expertise to peripheral hospitals (figure 3). India's OncoNET[50] project for public hospitals is one such initiative that has reduced the burden of referrals to tertiary centres and improved cancer care and education in peripheral hospitals. Datta and Rajasekar[3] proposed a three-tier model for radiation therapy facilities in India that depends on resources available at each level of therapy. Similar initiatives exist for pathology in Russia[57] and for paediatric oncology in Brazil.[51] A similar telemedicine programme (applicable to teleoncology) is being developed in Argentina to connect hospitals in rural areas with tertiary centres.[64]

Support of clinical investigation

Many of the advanced cancer centres in upper-MICs are equipped to participate in international clinical trials, but other centres might benefit from assistance in developing the regulatory and clinical best practices necessary to support such trials. Telecommunications offers a feasible approach to the training and mentoring of health-care professionals to help set-up and oversee participation in clinical research. The integration of teleoncology into international clinical trials will also help to ensure data

Search strategy and selection criteria

Data for this health-care development were identified by searches of Medline and PubMed by use of the search terms "teleoncology", "telemedicine", and "cancer" or "chemotherapy". Abstracts and meeting reports were excluded. Only reports published between January, 1982, and November, 2009, were included. Further information was found from the following websites: the World Bank (www.worldbank.org), the United Nations (www.un.org), and the world fact book at the Central Intelligence Agency website (www.cia.gov).

integrity and patient safety in both LMCs[71] and HICs,[40–42] and will create local capacity for clinical investigation. Teleoncology may also allow more cancer centres in MICs to participate in clinical trials, thus expediting accrual—a particularly important consideration in rare cancers—and benefiting all participants.

Improvement of quality of life of cancer patients

Cancer is commonly accompanied by suffering—pain, dyspnoea, and other discomfort. However, resources and expertise in palliation are least likely to be available and suffering is least likely to be adequately addressed in LMCs,[72] especially in rural areas.[73] Telemedicine has been used in hospice care,[30] and similar uses should be explored in LMCs. Telemedicine links between HICs and LMCs can be established to improve palliative care in major centres, and links between resource-rich and resource-poor institutions within LMCs can improve palliative care in remote or rural areas.[73] Such links should also be explored to provide or improve ancillary services such as rehabilitation, social work, child life, and others needed to optimise quality of life in cancer patients.

Conclusion

Teleoncology is not a panacea for global oncology problems; if it is not used wisely, or if the human factor is not addressed, it can even exacerbate existing problems. Implementation of teleoncology should be guided by local communities' needs and introduced to potential stakeholders as a pragmatic means of enhancing access to oncology care. Local professionals should be recruited as stakeholders and provided with thorough training. When done well, teleoncology is, as Furtado commented, the "next-best thing to being there."[74]

Contributors

RH and IQ were responsible for the conception, design, literature search, data collection, data analysis, manuscript writing, and final approval of manuscript. IQ provided the figure design.

Conflicts of interest

The authors declared no conflicts of interest.

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