トのサービスながら、月々数千円の負担で１～１００Mbpsの帯域が得られる。一方でこのような広域ネットワークでは、類型的に要保護性の高い医療情報を扱う上では、高度にセキュリティを確保することが要求される。外科領域における遠隔手術指導では高画質な動画像がリアルタイムで伝送されることが必須の条件となるが、このような大容量の情報を強固に防御するには、従来、高性能のコンピュータを必要としたため実用化が困難であった。そこで暗号強度と通信速度が両立可能な新しい暗号技術により高いセキュリティーを確保しつつ、インターネットを介してリアルタイムに動画像を転送しうるシステムを構築した。これを用いて腹腔鏡補助下幽門側胃切除術（ＬＡＤＧ）や内視鏡的胃粘膜切除術（ＥＭＲ）の遠隔指導を安全に施行しえた。帯域保障のないベストエフォート型のサービスであっても、比較的安定した環境で動作しうるため、今後、広く普及する可能性があると考えられた。

（４）遠隔カンファレンス

遠隔カンファレンスは、遠隔指導に比べてデモンストレーションやディスカッションが主体となるが、リアルタイム性と双方向性を求められる点で、技術的には共通の部分が大きい。遠隔指導は２地点間となることが多いが、遠隔カンファレンスは多地点間を接続することでその有用性が高まるとされる。

我々は2000年2月、京都大学と連携して国内初の2病院間ドミノ肝移植を行った11)。アミロイドポリニューロパシー（ＦＡＰ）の20代男性患者摘出した肝臓を東京から京都大学に運ぶにあたり、緊密な連携が不可欠と考え、周術期にテレカンファレンスを併用し良好な結果を得た。

（５）遠隔共同手術

我々は、実用的な遠隔手術の形態として、遠隔共同手術システムを開発し臨床応用した。その概要を紹介する。

症例は４９歳、女性、有症状の胆石症患者である。東京医療センター倫理委員会の承認を経て、患者に説明し事前に文書で同意を得た。

内視鏡はオリンパス社製ImageTrack®を用い、遠隔支援コントローラーは、EndoALPHA®を利用した。デジタル画像伝送装置は富士通ネットワークテクノロジー社製DVSTREAM II®を用いた。通信回線は日本テレコム社のWide-Ether®（70Mbps、外部からアクセスできない閉域網）を利用し、相方向のＤＶＴＳで動画像転送を行った。

2004年3月25日、胆石症に対する腹腔鏡下胆嚢摘出術において遠隔共同手術を行い、安全かつ効果的に内視鏡外科手術を遠隔地の指導医と共同で施行しうることを確認した（図１）。

低侵襲で、整容的にも優れた内視鏡外科手術に対する社会的ニーズは今後も高まると考えられる。一方で最近になり、開腹手術に比べ高度な技術を要する内視鏡外科手術に対して、さらなる安全性を求める世論が高まってきている。そこで、外科医には絶えず新たな手術手技を習得することが要請されるわけであるが、従来、この修練のためには、自ら専門施設へ赴くか、指導医を招いて指導を受けることが一般的であった。そこで本研究は、情報技術を応用して、効率的に難易度の高い内視鏡外科手術の普及を可能とする遠隔手術支援システムの構築をめざした。

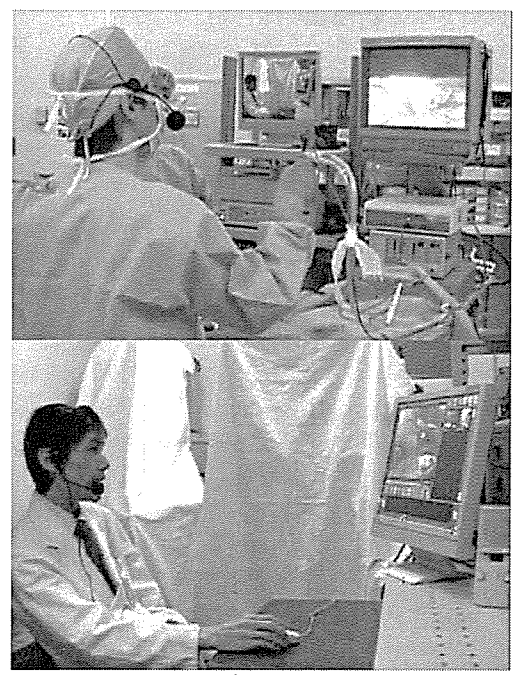

図１　遠隔共同手術

従来の遠隔手術指導では、手術は手術室内の執刀医と内視鏡を操作する助手により行われ、指導者は遠隔地より音声とアノテーション機能を用いて助言を行うのみであった。一方、共同遠隔手術では、手術の機器の操作などは手術室の執刀医により行われ、遠隔地の指導者が助手として内視鏡の操作を行いつつ、適切な視野を提供しつつ手術に対する助言を有効に行いうる点が特徴である（図２）

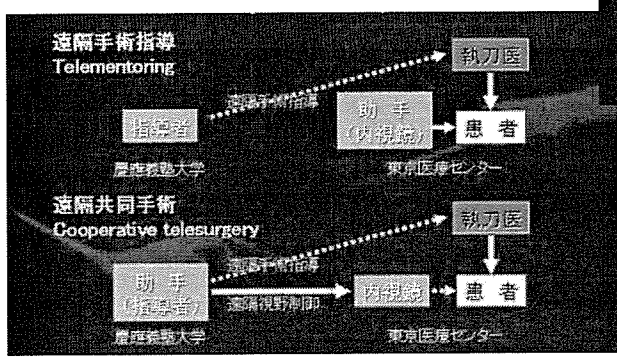

図２　遠隔手術指導と遠隔共同手術の関係

2001年、世界で始めて臨床において遠隔手術としてLindbergh手術が行われた。遠隔手術は将来的な実用に向けて研究を進めていくべきであるが、現状では安全性やコスト面などで解決すべき問題が数多くある。一方、遠隔共同手術は、ロボットなどの特殊な設備や多くの人員を必要とせず、執刀は手術室の医師により行われるため、安全性が確保されている。またコスト面でもより現実的であり、現段階において普及可能な遠隔手術システムになりうると考えられた（図３）。また指導医が視野制御を直接行い適切な術野を提示しうるため、従来の遠隔手術指導に比して、特に難易度の高い内視鏡外科手術、頻度の少ない内視鏡外科手術、人員の少ない病院の診療援助などの面で臨床的有用性が期待される。今後、高速通信環境の整備に伴い本システムが普及すれば、内視鏡外科手術の質向上および医療安全に大きく寄与する可能性があると考えられた。今後は、広域ネットワーク利用を念頭においた、セキュリティ対策、インターフェースの改善、普及に向けた低価格化、法整備（診療報酬、有害事象の責任・補償）などが不可欠であると思われる。

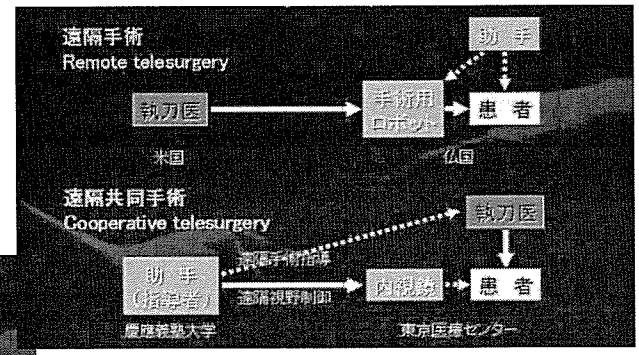

図３　遠隔手術と遠隔共同手術の関係

【米国における医療安全教育とＩＴ技術】

．ＭＭＶＲ

IT技術を用いた医療教育訓練システムに関する米国で最も有名な学会であるＭＭＶＲ2007（Medicine Meets Virtual Reality）（図４）に参加し情報収集した。

会場では、スタンフォード大学LeRoy Heinrichs教授と外科領域における医療安全教育に関して討論した。Heinrichs教授からは、Consultancy Proposalとして、“Web-based, Flexible Simulation-based Training and Assessment of Technical Surgical Skills”とする提案をいただいた（別添資料）。米国での医療安全教育への取り組みが、国際的に利用可能となる事例として意義のあるものと考えられる。

図４　ＭＭＶＲの会場の様子

２．スタンフォード大学

IT技術を用いた医療教育訓練システムに関して、ＶＲ技術を利用した教育・研究施設として世界をリードするSUMMIT（Stanford University Medical Media and Information Technologies）（図５）を訪問した。

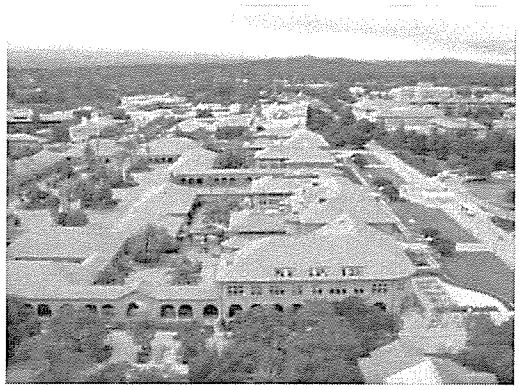

図５　スタンフォード大学

SUMMITでは数多くのシミュレータ（図６）が開発・改良されており、また実際に医師の研修に使用されていた。さらに、受講者の評価も行われており、その先進的な取り組みがみられた。

図６　SUMMITのシミュレータ

３．Beth Israel Deaconess医療センター Carl J. Shapiro Simulation and Skills Center

ハーバード大学 Center For Medical SimulationのJeffrey B. Cooper教授から、外科系の医療安全教育に積極的に取り組む施設として、Beth Israel Deaconess医療センター Technical Skills and Simulation Labを紹介された。責任者のDaniel B. Jones教授に会い、この施設としての取り組みと、米国の外科学会としての取り組みを学んだ。（図７）

図７　Beth Israel Deaconess医療センター Carl J. Shapiro Simulation and Skills CenterのTheatre I: Operating Room

４．Brigham and Women’s病院のCenter for Medical Simulation

さらにBrigham and Women’s病院のCenter for Medical Simulation（図８）を訪問し、Stephen J. Nelson教授より説明を受けた。この施設は、主として救急医学とＩＣＵでのチーム医療のトレーニングを行っており、医療安全を推進する上でクリティカルな部分を担っていることが認められた。

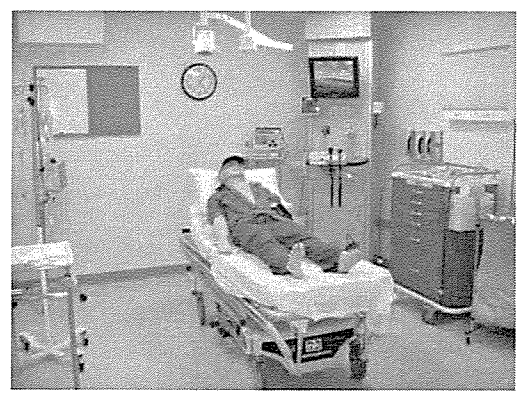

図８　Brigham and Women's病院のCenter for Medical Simulation

５．ボストン小児病院

ボストン小児病院では、乳幼児のマネキンを用いた看護師のシミュレーション（図９）を視察した。専門の技術者がマネキンの状態をコントロールして、より効果的に看護学生の教育を行っていた。

図９　ボストン小児病院

E．結論

「人」に対する医療安全対策を効率的に推進する上で、ＩＴを利用した教育システムは有効性が示されつつある。

わが国での普及のためには、コスト・ユーティリティの検討や、インターフェースの改善が必要と考えられた。

F．健康危険情報

（分担研究報告書には記入せずに、総括究報告書にまとめて記入）

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H．知的財産権の出願・登録状況

（予定を含む。）

1. 特許取得　　なし
2. 実用新案登録　なし
3. その他　　なし

（資料_和田 1）

Consultancy Proposal

Web-based, Flexible Simulation-based Training and Assessment of Technical Surgical Skills

In collaboration with
SiMETT Partners, USA
(Simulation in Medical Education and Team Training)
Palo Alto, CA

Specially Prepared for
Health Ministry of Japan
Submitted March 2007

Contents

1. Background

The past few decades have witnessed exponential growth in medical knowledge and t he introduction of many novel diagnostic and therapeutic procedures in routine clinic al practice. This changing scenario creates the opportunity for developing a new par adigm in medical training that is efficient, effective, economical, and promotes the cul ture of life-long learning.

Driven by concerns of patient safety and the increasing cost of health care, developm ent of technology-augmented medical education and simulation based clinical skills tra ining has been widely adopted in leading medical centers around the globe. Simula tions range from low-tech, low-cost, physical simulators to high-end, virtual reality ty pe simulations and include web-based applications. Some require the participation of instructors, and others afford self-study efficiencies.

Integration of cognitive knowledge with technical skills in a pedagogically sound man ner is essential for successful simulation based training. This affords the trainee the opportunity to learn a variety of skills for individual dexterous actions and also those involved in team participation. Several studies in recent years clearly demonstrate t hat training on surgical simulators lead to the acquisition of skills that are transferabl e to the operating room; efficiency is improved and error rates are lowered.

The traditional subjective training methodologies based on chance patient encounters ("training by serendipity") are being challenged and supplanted by an objective and more structured series of planned clinical experiences. Multimedia, databases, simulati on technologies, and networked applications are being adopted to address medical an d surgical training needs of the 21st century.

2. Prior experience

The principals of SiMETT Partners. form an interdisciplinary team and have worked t ogether for over a decade. This team maintains an excellent track record in using si mulations for basic and advanced surgical training. Several peer-reviewed publication s and numerous presentations at national and international conferences have resulted from this work.

The principals of SiMETT Partners. have studied a range of simulators spanning from low-cost physical simulators at one end to the high-end virtual reality simulators at t he other. Rigorous evaluation of these simulators from technical and pedagogical sta ndpoints has lead to an understanding of their advantages and limitations. A judicio us combination of a variety of simulators, and their phased introduction into a trainin g program, results in cost-effective utilization in a pedagogically sound manner.

The principals of SiMETT Partners. have completed several studies in the past that ha ve been in collaboration with commercial entities, service hospitals, and academic bodi es. One focus area of these studies is on the research and development of technical aspects of simulators including multimedia, graphics, haptics, networking, metrics, perf ormance, and reliability. A second focus area of these studies is on validation of the se simulators from an educational point of view.

The principals of SiMETT Partners. have worked closely with numerous international partners in Canada, Sweden, Australia, Korea, and India, and successfully completed s everal projects.

3. Customized solutions

SiMETT Partners follow the philosophy of customized solutions for each client. The usual path is a three-step process – Planning, Implementation, and Evaluation. This PIE protocol affords the best possibility of meeting the individual needs of our clients.

These three steps are further elaborated below:

1. *Planning* – This is the first step in our customized solution paradigm and involves one or more interactive sessions (usually one to four sessions). These sessions typically last from one-half day to two days in length and are a mixture of presentations, discussions, observations, and analyses. The goal of these sessions is to define client needs, formulate and agree on an implementation plan, establish milestones, and decide on an appropriate evaluation focus.

2. *Implementation* – This is the second step in our customized solution paradigm and involves carrying out the plan defined in the first step. Depending on client needs the duration of this phase may extend from a few months to several years. The work involved in this phase can vary widely, ranging from conducting standard research studies to "train-the-trainer" type activity. The end-goal of this step is to have an "up-and-running", effective and efficient simulation center.

3. *Evaluation* – This is the third step in our customized solution paradigm and is an iterative process. Continuous evaluation is conducted throughout the implementation phase. The end result from this evaluation is further input to help fine tune our implementation plan and guides us in successful and timely completion of the implementation phase with optimum outcomes.

4. Specific Solutions for Learning

• SiMETT Partners provide expertise in planning and implementing surgical simulatio n skills centers, and evaluating skills performance of laparoscopic surgeons. First-han d comparative knowledge of many commercial simulators, and those able to be netwo rked for distance learning provides a strong basis for designing training centers. Pr oviding benchmark data from experienced laparoscopic surgeons enables training prog ram directors to establish customized curricula and criterion-based assessments.

• SiMETT Partners provide online, flexible assessment and training in basic surgical t echnical skills using surgical simulators. This education and training support service is applicable for physicians in training and for graduate physicians who seek either i mprovement or maintenance of their surgical skills. Clients who seek to develop a da tabase for a hospital, a province, or a country's Health Ministry can achieve that goal through the services of SiMETT Partners. Local partners will be incorporated for ac hieving acceptance and for overcoming language barriers, if that is relevant.

• An emerging trend in healthcare training is using videogame technology to create 3D Virtual World environments that are web-based, and allow users to play the role of a health care professional, who is interacting in real-time with virtual patients and colleagues in a Virtual Hospital. All characters in the Virtual Hospital role-play are o perated by trainees and instructors who simulate realistic scenarios representative of a ctual clinical care in the hospital setting. Many different environments can be simulat ed, and customized for individual facilities or institutions.

• SiMETT Partners provide established expertise in designing, developing, and trainin g for critical medical and nursing care in Virtual Worlds. Our previous study of the cost-, and time-effective training of medical students, and for the advanced training of specialists in Emergency Medicine, has demonstrated the probable value of building an entire Virtual Hospital for training these and other healthcare disciplines. Parts of a Virtual Hospital have been constructed, and more critical care components are plan ned. SiMETT Partners provide, jointly with its' collaborators, a short-term, realizable s olution to distributed, effective learning.

• Team training for critical care professionals in Emergency Medicine and Surgery h as been pioneered by the principals of SiMETT Partners. By implementing lower-cost learning technologies in Virtual Worlds, co-designed with Forterra Systems, Inc., SiME TT Partners are able to offer to its' clients effective and validated scenarios to initiate a process of training-the-trainers who are then able to develop applications of their unique interest on the software- platform. Assessment methods for individuals and tea ms are provided in this service.

5. Proposal by SiMETT Partners

SiMETT Partners offer multiple options for completing the first phase (Planning phase) of work based on the PIE philosophy described above. Depending on the outcomes of this phase, a follow-on comprehensive proposal will be submitted for the Implementation and Evaluation phases. Our clients may chose the option best suited for them based on their perceived needs and budgeting.

On-site consultancies

Option 1 – One-half day consultancy

This option includes one-half day of consultancy with the SiMETT Partners team. This session will involve presentations by the team and discussions between team members and client's representatives to understand their needs and resources. This session takes place at the SiMETT Partners offices in Palo Alto, California.

Option 2 – One full day consultancy

This option includes one full day of consultancy with the SiMETT Partners team. This session will involve presentations by the team and discussions between team members and client's representatives to understand their needs and resources. This session will also include a field trip (duration approximately two hours) to the laboratory facilities at Stanford University. This session takes place at the SiMETT Partners offices in Palo Alto, California.

Option 3 – Two full days consultancy

This option includes two full days of consultancy with the SiMETT Partners team. This session will involve presentations by the team and discussions between team members and client's representatives to understand their needs and resources. This session will also include a field trip (duration approximately four hours) to the laboratory facilities at Stanford University. This consultancy will include a formal report compiled by the consultants and submitted to the clients within a four weeks period. This session takes place at the SiMETT Partners offices in Palo Alto, California.

Off-site consultancies

For off-site clients (within US, Canada, Mexico, or internationally) that find it difficult to make a trip to the Bay Area, off-site consultancies can be arranged. The followin g options are available:

Option 1 – Video-conference consultancy

This option includes a video-conference session with the SiMETT Partners team. This session will involve presentations by the team and discussions between team membe rs and client's representatives to understand their needs and resources.

Option 2 – One full day consultancy

This option includes one full day of consultancy with the SiMETT Partners team whe re the team travels to the client's premises. This session will involve presentations b y the team and discussions between team members and client's representatives to und erstand their needs and resources. For off-site consulting, additional team members m ay join in via videoconference, as the need arises. This consultancy is restricted to clie nts within the US, Canada, and Mexico only.

Option 3 – Two full days consultancy

This option includes two full days of consultancy with the SiMETT Partners team wh ere the team travels to the client's premises. This session will involve presentations b y the team and discussions between team members and client's representatives to und erstand their needs and resources. For off-site consulting, additional team members m ay join in via videoconference, as the need arises. This consultancy will include a fo rmal report compiled by the consultants and submitted to the clients within a four w eeks period. This consultancy is best suited for international clients.

6. Financials

The following summarizes charges for the various consultancy options. Details of various options are given in section 5 (Proposal by SiMETT Partners). Pricing is firm through June 30, 2007. Accounts are payable within 10 days from completion of service.

On-site consultancies (maximum number of participants is eight)

Option 1 – One-half day consultancy - $3,000 (does not include visit to Stanford University facilities)

Option 2 – One full day consultancy - $6,000 (includes a 2-hour visit to Stanford University facilities)

Option 3 – Two full days consultancy - $15,000 (includes a 4-hour visit to Stanford University facilities and a follow-on formal report)

Off-site consultancies (no maximum number of participants)

Option 1 – Video-conference consultancy - $1,500 (2 hours duration)

Option 2 – One full day consultancy - $7,000 + travel (air and local) and local hospitality for a 2-member, off-site consultant team – additional consultants are $2,500 each + travel and local hospitality

Option 3 – Two full days consultancy - $12,500 + travel (air and local) and local hospitality for a 2-member, off-site consultant team – additional consultants are $5,000 each + travel (air and local) and local hospitality

7. Consultant Team

Parvati Dev, PhD

Chief Technical Officer, SiMETT Partners.

Dr Dev has a PhD in Electrical Engineering from Stanford University and has more t han 30 years of experience in technological development for medicine and biology. Her research work spans networked simulations, medical imaging, computer-based mo deling of anatomy and physiology, and Internet-enabled learning environments. More recently, she has focused on simulation based-learning environments in medicine, and their deployment over advanced networks. She has successfully led an interdisciplin ary team of researchers at Stanford University for over a decade that works in the fie ld of simulations for clinical training.

William LeRoy Heinrichs, MD, PhD

Chief Medical Officer, SiMETT Partners.

Dr. Heinrichs is a Professor (Emeritus, Active) and Past Chair of Obstetrics and Gyne cology at the Stanford University School of Medicine. He is a Reproductive Endocrin ologist, and early adopter of laparoscopic surgery. He has for a decade promoted su rgical simulation by building 3D models for simulators, defining a vocabulary for desi gning simulators, and leading the thought-charge among surgical educators about this technique for learning surgery. He is recognized nationally and internationally as a strong advocate of using simulations for surgical training.

Sakti Srivastava, MBBS, MS

Chief International Officer, SiMETT Partners.

Dr Srivastava is an orthopaedic hand surgeon with additional qualifications in comput er technology and applications. Trained at the All India Institute of Medical Sciences, New Delhi and in the UK, he has been at Stanford University School of Medicine fo r eight years during which time he has been a core member and content lead on sev eral projects related to computer-aided medical instruction and clinical teaching using simulation technologies. He has successfully worked on several international collabora tions requiring strong coordination skills and cultural sensitivity. Dr Srivastava is the Director of the Stanford-India Hand Surgery Program, and is an Adjunct Professor at the Indian Institute of Technology, Delhi.

Patricia Youngblood, MA PhD

Chief Education and Evaluation Officer, SiMETT Partners.

Dr Youngblood 's background is in teaching, faculty development, instructional syste ms design, curriculum development and educational evaluation. She has a PhD in E ducation (Curriculum and Instruction, 1989) from the University of North Carolina in Chapel Hill. Subsequently, she lived and worked in Australia for eleven years; first

as a Senior Instructional Designer/Project Manager for Andersen Consulting (now Acce nture), and then for seven years taught Instructional Design and Educational Evaluati on in the Master of Health Professions Education program at the University of New South Wales, where she also served as Curriculum Consultant for the School of Medi cine. Since 1998 she has been working at Stanford University, assisting with the evalu ation of several projects that involve simulation based teaching.

Innovations, Achievements and Affiliations

- **1997 Awardee of a National Science Foundation (NSF) grant for developing a ne w learning technology for instruction is biology. With this funding, SUMMIT dev eloped its first Virtual World, Frog Island. It was used in countless schools and b y home-schooler's, internationally.**

- **2003 Awardee of a gift from Adobe Systems, Inc. for developing a Virtual Emerg ency Department (Virtual ED I) called SimTech. This flexible learning technology compared favorably with a high-fidelity manikin –based simulator.** http://summit.st anford.edu/simtech/

- **2004 Awardee of the Satava Award – MMVR (Medicine Meets Virtual Reality) f or Excellence and Leadership in Surgical Simulation. Awarded to SUMMIT (Stanf ord University Medical Media and Information Technologies), Parvati Dev, Director, Wm. LeRoy Heinrichs, MD, Associate Director.**

- **2004 Co-Awardee (SUMMIT & Karolinska Institutet, Stockholm) of a Wallenber g Grant for developing a Virtual High School for training students in the skills of Cardio-pulmonary Resuscitation (CPR). Two follow-on grants have afforded studie s that demonstrate the effectiveness of this training method.** http://summit.stanford. edu/simergency/

- **2007 Awardee of the CENIC 2007 Innovations in Networking Award for High P erformance Research Applications for the iAnatomy initiative. This award to SUM MIT recognized the distance learning project with the Northern Ontario, Canada Sc hool of Medicine's implementation of iAnatomy.**

- **Affiliation with Stanford University School of Medicine, Stanford University Ho spital and Clinics, and the Lucille Packard Children's Hospital:**

    - **Stanford University Hospital and Clinic's Nursing Staff have earned the 2007 MAGNET recognition bestowed by the American Nurses Credentialing Center (ANCC). This accolade is the only one given to an academic medical center in Northern California in 2007;**

- Lucille Packard Children's Hospital is ranked for the 5th year among the ten best Children's Hospitals in North America;

• Drs. Dev and Heinrichs are Consultants to Forterra Systems, Inc., a videogame development company located in San Mateo, CA, Orlando, FL, and New York City, NY. This company was awarded a SBIR grant in 2005 under which the SUMMIT team of Dev, Heinrichs, Youngblood and Srivastava have provided the curriculum, team assessment tools, patient scenarios, and the physiological human model for two in-hospital emergency medicine training programs. In this Virtual ED II, multi-victim, multi-player scenarios for nerve toxin and 'dirty' bomb disasters, provide flexible, team training exercises. http://forterrainc.com/medical.html

III. 研究成果の刊行に関する一覧表

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