1

# Data Integration and Management in Cardiac Surgery

Alessandro Taddei[1,2], Maurizio Mangione[1], Paolo Marcheschi[1] and Stefano Dalmiani[1]
[1]*Medical Informatics, Gabriele Monasterio CNR / Tuscany Region Foundation,*
[2]*CNR Institute of Clinical Physiology, G. Pasquinucci Heart Hospital, Massa*
*Italy*

## 1. Introduction

Today information and communication technology is widely applied in health care. A variety of Information Systems for management of both administrative, government and clinical tasks have been developed and largely implemented in hospitals. Cardiac surgery setting is peculiar in terms of complexity of health-care information management, involving in addition to general tasks related to hospital patient care (ADT, DRG billing, cost evaluation, multimodality diagnostic examinations, laboratory tests, ward and nursing care, anesthesia and surgical interventions, follow-up) specific procedures for cardiac function evaluation and care (cath-lab, radiology), heart surgery (from minimal invasive to open heart operations with assisted circulation), intensive care unit monitoring.

Given the huge amount of different heterogeneous sources of patient data, both administrative and clinical, integration is crucial to allow comprehensive medical decision making, effective care planning and proper resource control. Actually few systems achieve this objective even if interoperability in health care has been promoted by many international initiatives (HL7, ANSI, CEN, DICOM).

Aim of this paper is to report our experience in developing an integration system to manage health care in its technological, administrative and clinical aspects, in respect of high quality care and cost-effectiveness evaluation.

Almost 15 years ago the Hospital Information System (HIS) was first developed at National Research Council (CNR), Institute of Clinical Physiology (IFC), in Pisa by the SPERIGEST project (supported by Italian National Health Ministry, 1995-98) (Macerata, 1995) for the integration of resources in Cardiology. Later, extension of HIS at G.Pasquinucci Heart Hospital (GPH), IFC-CNR's section in Massa, 60 kilometers from Pisa, specialized in Cardiology and Cardiac Surgery (both adult and pediatric), required both adaptation and development. In 2007 IFC-CNR health-care activities converged into the "G.Monasterio Foundation" (FGM) by the joint effort of CNR, Tuscany Region and Universities.

A networked computer-based information systems was implemented, based on three levels of data archiving (administration, clinical system and functional units, i.e. diagnostic laboratories, care units, Operating Rooms) and on two modalities for data exchange


Fig. 1. Gabriele Monasterio CNR / Tuscany Region Foundation, Pisa and Massa, Italy

(middleware data integration into the central clinical database ARCA and Web distribution of health care information over the HIS network). PACS was set up using Open Source DICOM utilities. The computer-network infrastructure, interconnecting GPH with the head institution in Pisa, allows achieving full access to patient information from any workstation. Secure Web technology was applied for distribution of health care information within hospital Intranet and also outside by Extranet.
The project of the information system was aimed at collecting, archiving and integrating all data related to patient care, from the visit in ambulatory to hospital admission, diagnostic procedures, cardiac surgery intervention and finally discharge and follow-up. The different

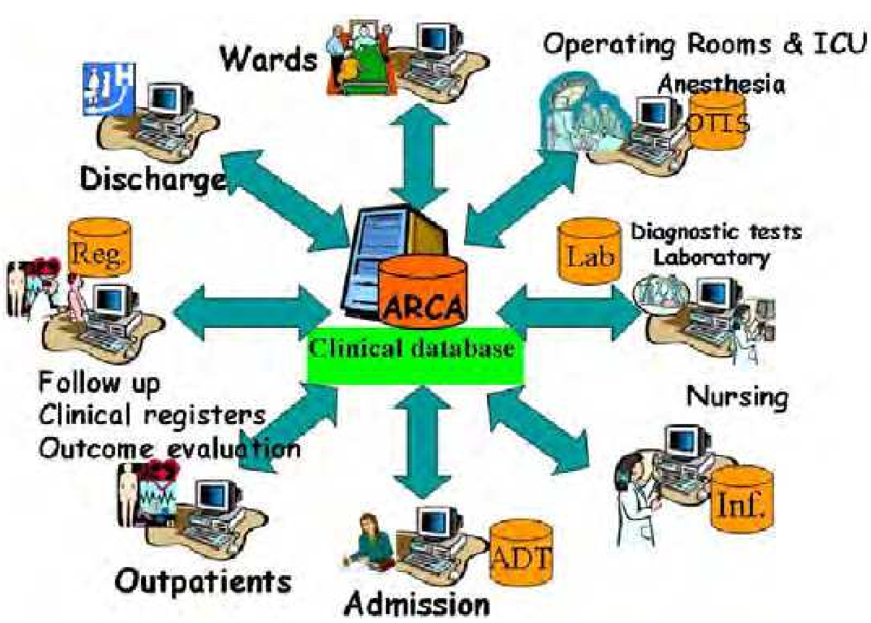



Fig. 2. The clinical information system: patient data flows

sources of patient information were integrated by middleware into the central hospital database (ARCA) which represents the clinical repository. Network connection between GPH and IFC is currently fast enough (8 Mb/s and recently up to 200 Mb/s) to guarantee effective access to patient data, archived in the ARCA repository located in Pisa (SQL IBM DB2/2, recently migrated into Oracle DB).

## 2. Electronic medical record

Transition from conventional paper-based towards electronic medical record (EMR) required, first, to set up regular and comprehensive patient information flow from health care units into ARCA repository (Taddei et al., 2003). Each diagnostic or care unit (ECG, echocardiography, cath lab, chemical lab, nursing system) as well as the Operating Room Theatre and the Intensive Care Unit were provided with computer-based systems for recording patient data and transferring reports into EMR. Structured data entry was generally implemented in addition to free text. Standard ICD9-CM codes of diagnoses and

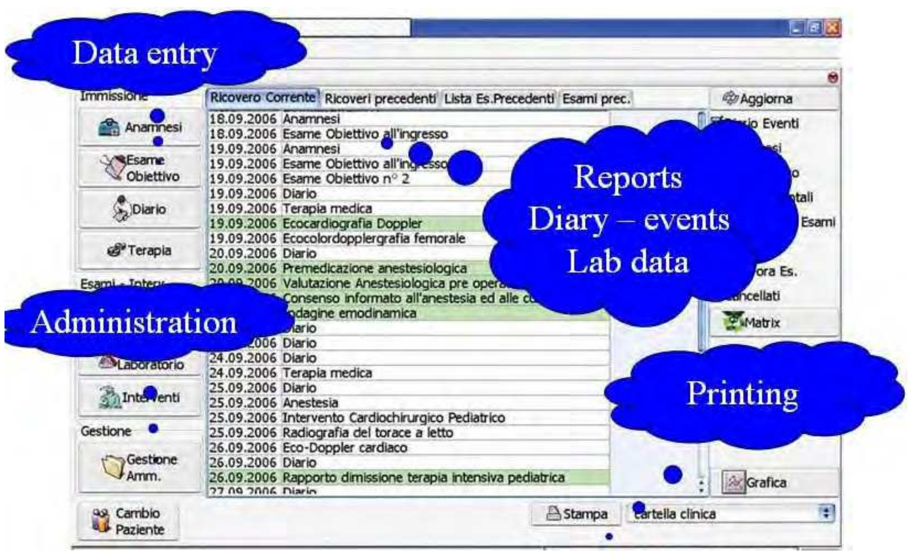



Fig. 3. The main GUI of the Electronic Medical Record

Fig. 4. Accessing the medical record in the ward by Wi-Fi connected laptop

procedures were applied for filling in DRG forms. EMR user interface was set up extending the model already used in Cardiology departments of IFC-CNR in Pisa (Carpeggiani et al., 2000). Use of Java language allowed to deploy EMR on any platforms (MS-Windows, Mac, Linux). Safe wireless networks were installed in the wards of both adult and pediatric cardiac departments to allow use of mobile EMR workstations at patient bed.

## 3. Operating room theatre

Development of HIS at GPH started with the set up of the Anesthesia Information Management system (Taddei et al., 2000) for documentation of anesthesia procedure during cardiac surgery operations. Commercial software (OTIS by Dedalus Inc.) for anesthesia data entry with on-line acquisition from OR equipment was adapted and integrated with HIS. Three phases were distinguished: preoperative patient identification and characterization, importing data from ARCA repository; intra-operative data entry (drugs, events, notes) and automatic data capture from OR equipment; post-operative ICU ordering, anesthesia record printing and data exporting to ARCA repository. Material data entry system was developed for resource management during operations. For each anesthesia record a surgery record was created automatically (by trigger on intervention start) in order to facilitate reporting by operators and to achieve OR register.

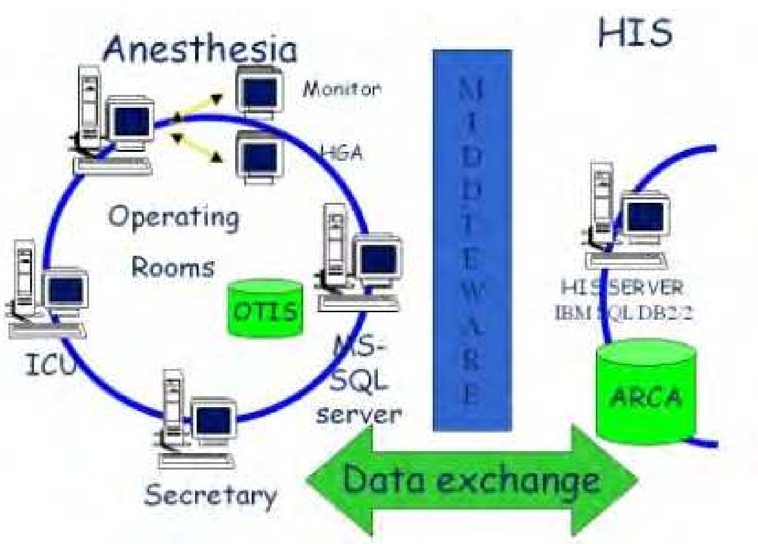



Fig. 5. Anesthesia Information System integrated with Hospital Information System

Recently a new Anesthesia Information Management System has been developed at the Heart Hospital in Massa (Cossu et al., 2011). It was specialized for recording anesthesia-related perioperative patient data during cardiac surgery on either adult or pediatric patients. The system was aimed at integrating patient data (clinical, instrumental and administrative) partly filled in by operator (anesthetist or anesthesia technician) through the Graphical User Interface, partly SQL-retrieved from Hospital Information System (Oracle), repository of patient electronic medical records, and partly gathered, by HL7, from Operating Room instrumentation (monitors, anesthetic machine and blood gas analyzer). Software was created in Java, achieving reliability and cross-platform capability. First, it was crucial to define requirements by interaction with anesthetists and later by cycles of test, revising and correction. GUI, designed to better ergonomics, was divided into modules, each for a corresponding task or phase of anesthesia. Specific forms are provided for documentation of induction phase, for recording staff, drug administrations (bolus or drip),

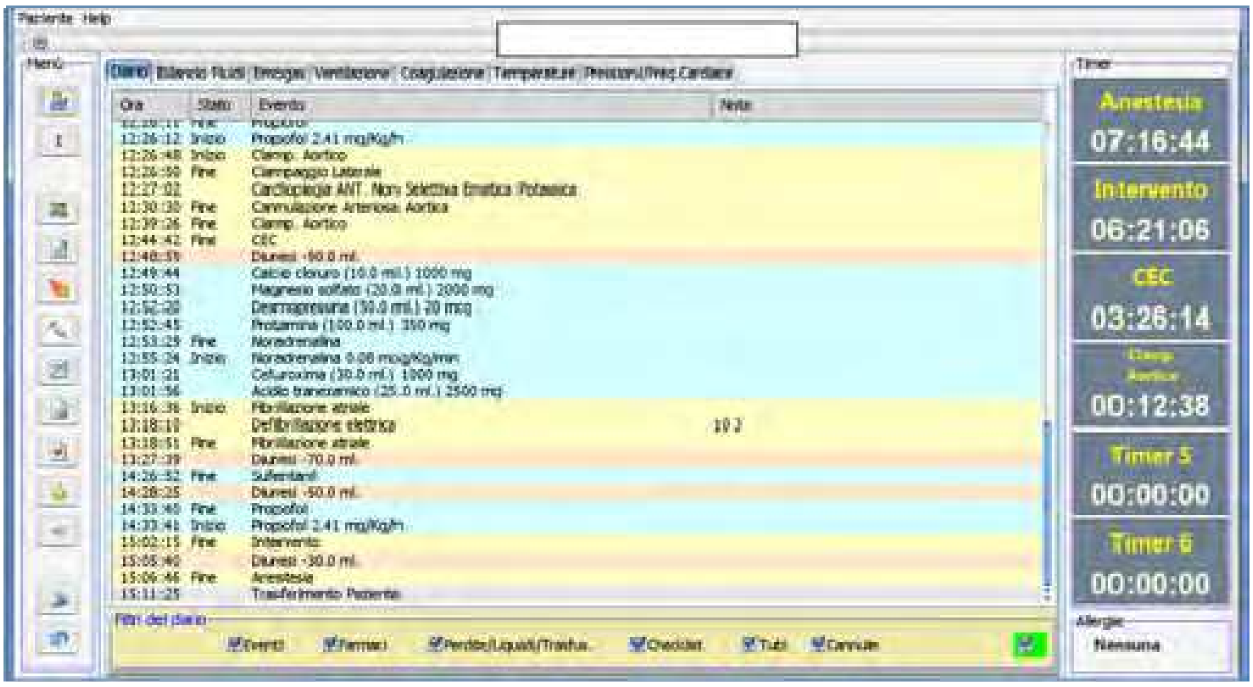



Fig. 6a. The main GUI of the new Anesthesia Information System: the diary (middle), the event counters (right), the tags for access to data views (top), the diary filters (bottom)

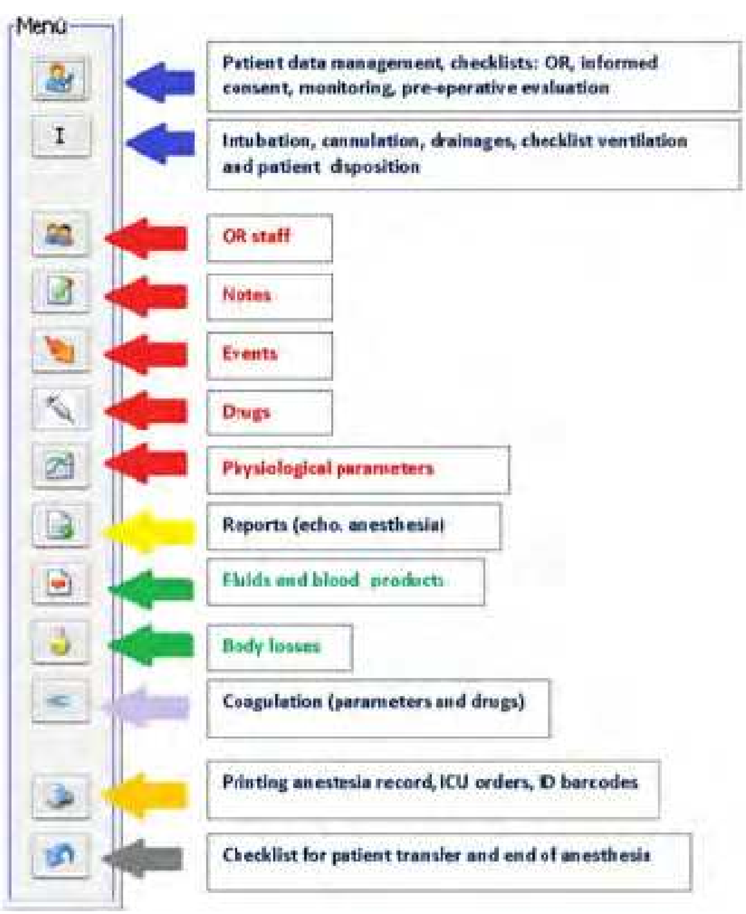



Fig. 6b. Data entry and printing

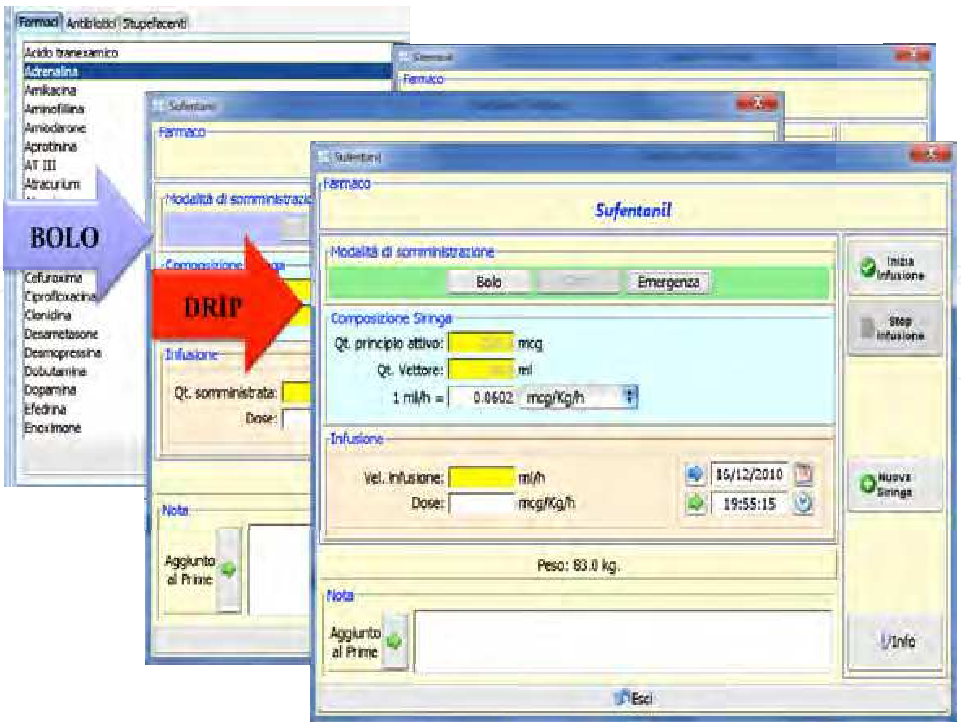



Fig. 7. Recording bolo/drip drug administrations and computing dosages and quantities


Fig. 8. Printout of anesthesia record

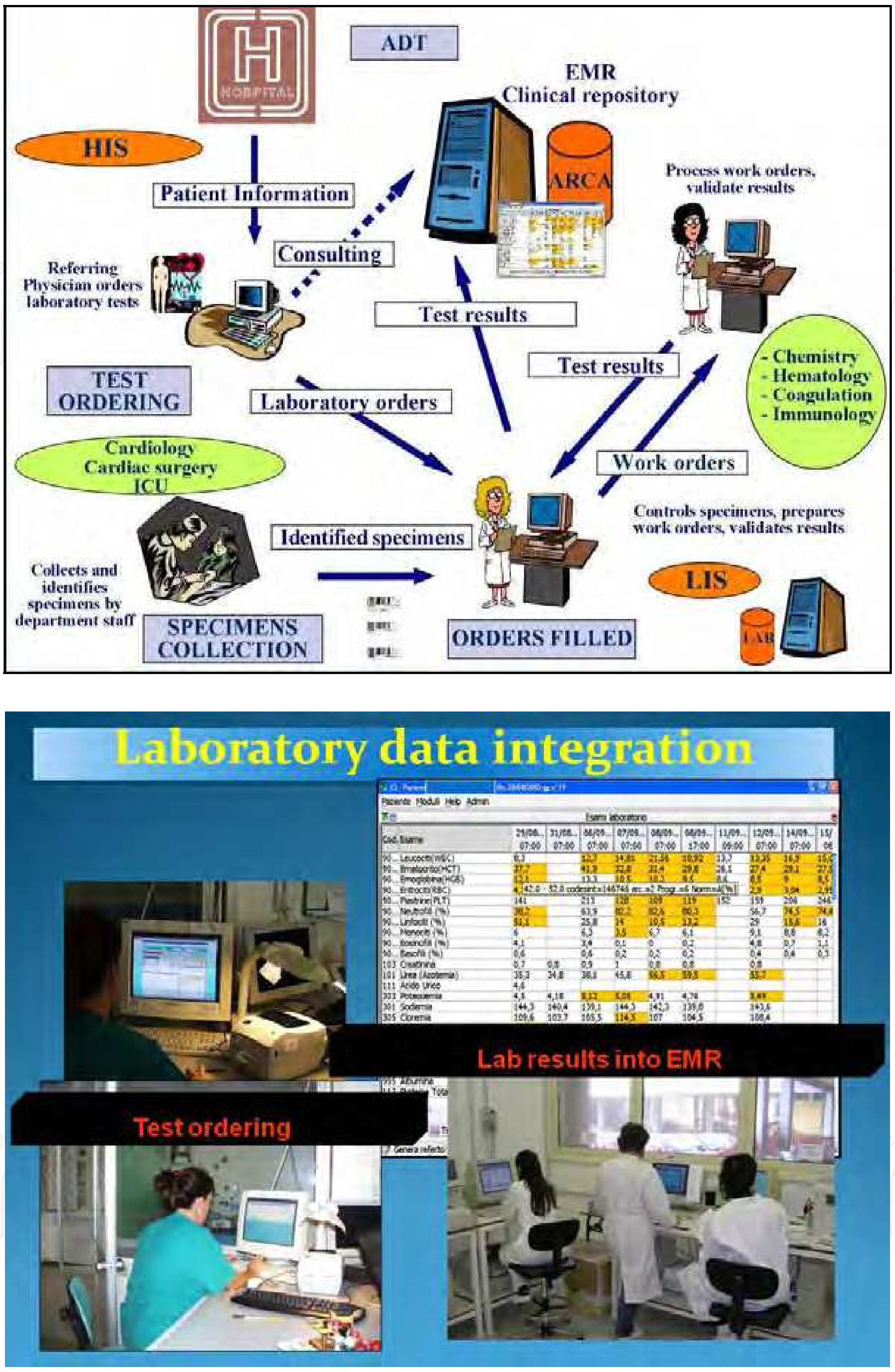



Fig. 9. From test ordering in the wards to laboratory processing and EMR reporting

fluid or blood administrations or losses, and any event of interest, for displaying physiological parameters, for echocardiography reporting. List of anesthesia-related information, fluid balance, lists or trends of physiologic, blood, ventilation, coagulation or monitoring parameters are represented. Counters for timing of main phases (e.g. anesthesia, surgery, ECC) are provided. Operation reports for surgeon’s convenience are automatically created in the HIS medical record at start of surgery. HTML reports are created, retrieving data from anesthesia database (Oracle), and printed out: “the anesthesia report”, i.e. the medical and legal document, and the “ICU report” addressed to personnel taking care of operated patient. AIMS was introduced in ORs since March 2011, using medical-grade computers close to patient bed. This system, adopting advanced IT solutions (Java, HL7, database relational), could be potentially deployed to other institutions, not limiting to cardiac interventions.

## 4. Laboratory information system

The LIS was integrated with the HIS to automate the testing process from clinical departments to laboratory and back into EMR (Taddei et al., 2005). Laboratory workflow consists of three parts: (a) test ordering by clinical staff, printing bar-coded ID labels and transmitting orders by network to laboratory; (b) processing test requests and controlling identified specimens by laboratory staff, providing work orders to analytical instruments and validation of results authorizing delivery into the hospital clinical repository.

## 5. Clinical registers

International reference data sets were adopted to characterize cardiac patients developing registers, aimed at both clinical research and outcome evaluation. An information model was created for structured data management to build clinical registers (Dalmiani et al., 2002). Registers were partially filled in automatically by data retrieved from EMR or from anesthesia record. EACTS congenital heart surgery dataset was adopted as reference for pediatric patients (EACTS database), while National Society of Cardiac Surgery dataset for adults undergoing cardiac surgery (SICCH database). Standard risk scores were derived from datasets (Euroscore for adult and Aristotle for pediatric cardiac surgery).

## 6. Web data distribution

Distribution of health care information over HIS network was achieved by the use of Web technology. HTTPS Web server was installed for secure access to clinical data recorded in ARCA repository. Web clinical site was developed for allowing authorized users, through password control, to browse into patient clinical data from any workstation over HIS network or even from Internet by VPN connection. First, CGI applications in C language

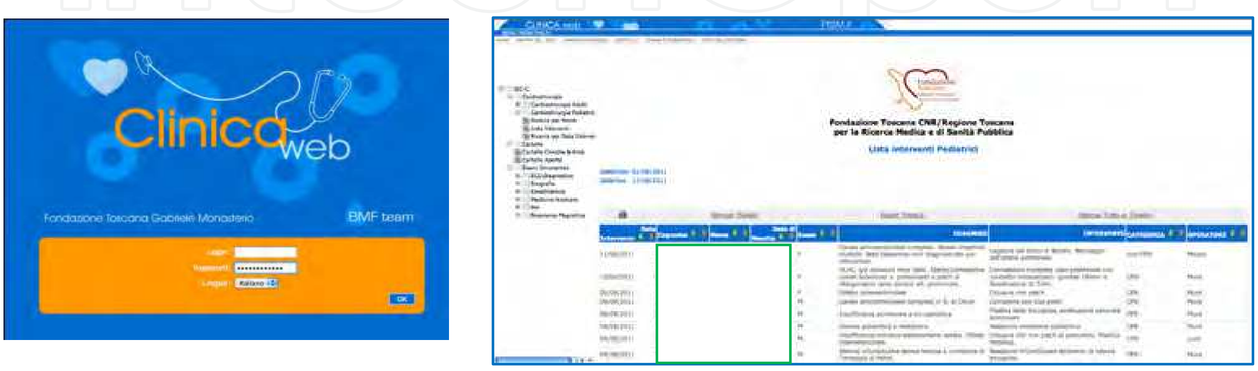



Fig. 10. From the clinical Web site: the list of cardiac surgery interventions.

and in NetData script (IBM) were realized and later Java servlets and PHP4 applications were developed. Tabular or graphic views were implemented for reporting medical records of in- and outpatients, discharge letters, lists of patients and diagnostic reports, cardiac surgery and anesthesia data. Data, downloaded from the web site, were further processed by statistical packages. Later a new web information systems (BMF) allowing deep user access control was developed; all administrative, clinical and government web applications were migrated and adapted (Mangione, 2006).

## 7. RIS-PACS

Using Open-Source utilities (DCM4CHE), the PACS for different DICOM modalities (CR, CT, XA, US) was set up, while viewer/processing workstations (OSIRIX) were installed for both reporting and consultation (OSIRIX). According to conformance statement of DICOM server (DCM4CHE) and modality equipment Work-List service was implemented was applied to get patient lists from HIS, thus allowing to identify examinations. Radiology workflow include the following steps: examination reservations (1) (in-or outpatients); execution of examinations, identified by worklist and recorded on DICOM server (2a,b); examination reporting on review workstation (3b) or on conventional films (3a); report data entry and printing by EMR (Taddei et al., 2008). Data security was maintained by RAID architecture and using CD/DVD automated DICOM backup systems.

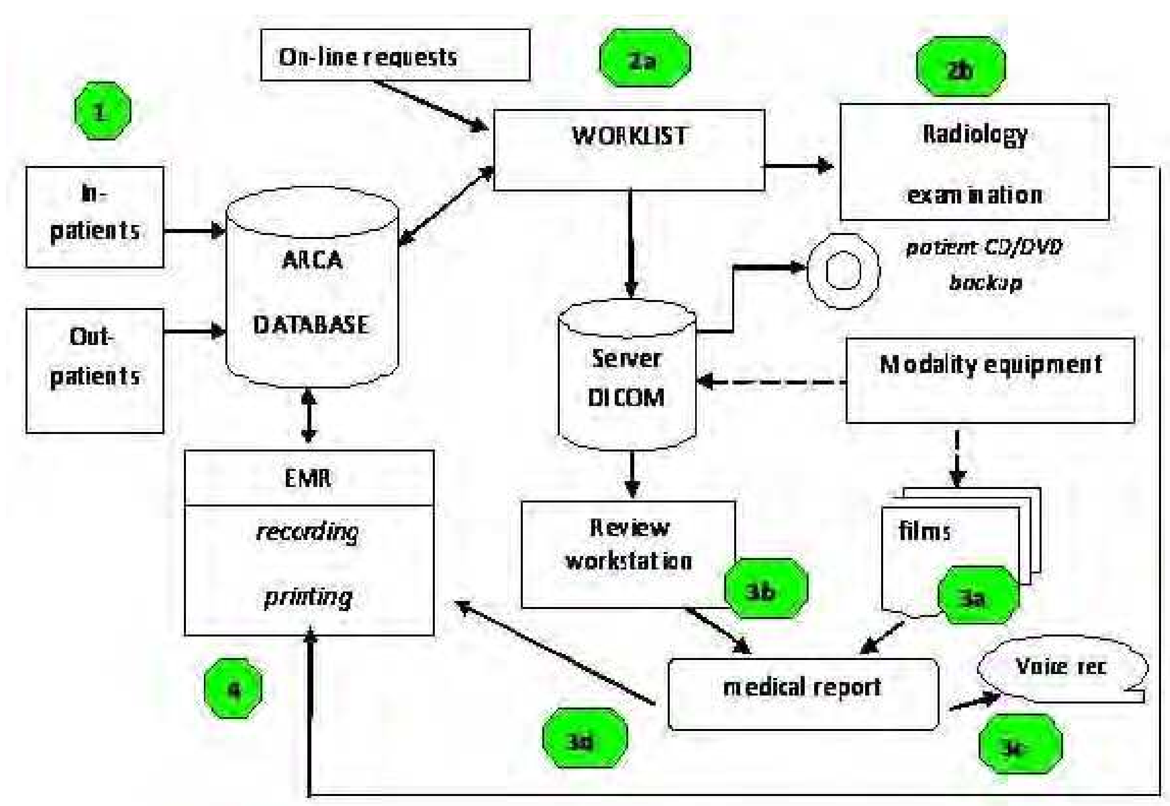



Fig. 11. The RIS structure

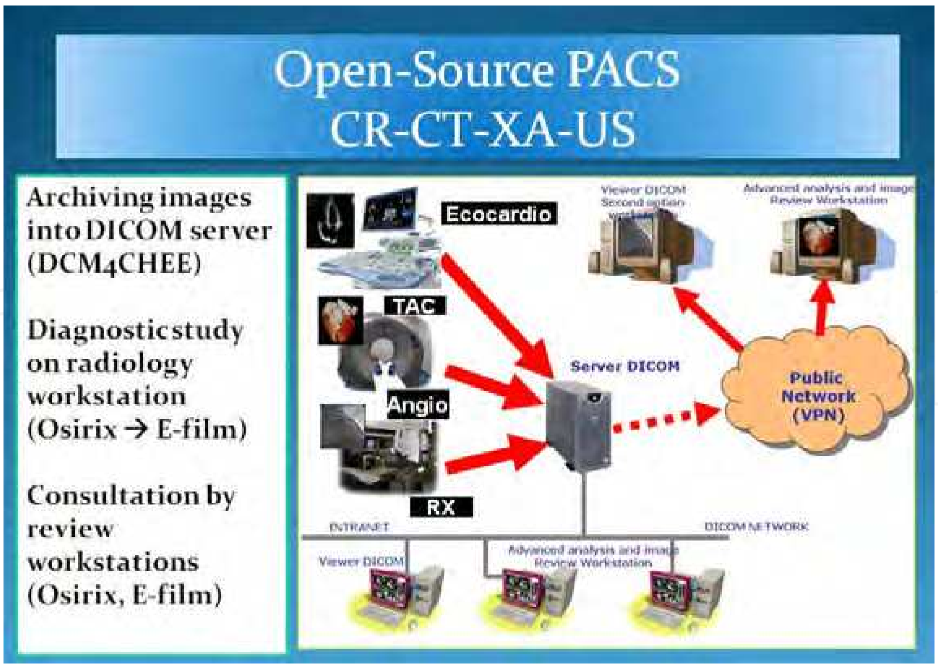



Fig. 12. The PACS

Fig. 13. Fetal tele-echocardiography

## 8. Telemedicine

Recently telemedicine applications were implemented by on-line secure transmission over Internet of echocardiography and angiography images over public network (project for tele-diagnosis between Balkan countries and GPH – Massa) (Taddei, 2011; Gori et al., 2010). Real-time capability is crucial for allowing specialists to drive remotely proper echo scanning of cardiac structures in patient or foetus with suspected congenital heart disease.


Fig. 14. Use of videoconferencing equipment in tele-echocardiography

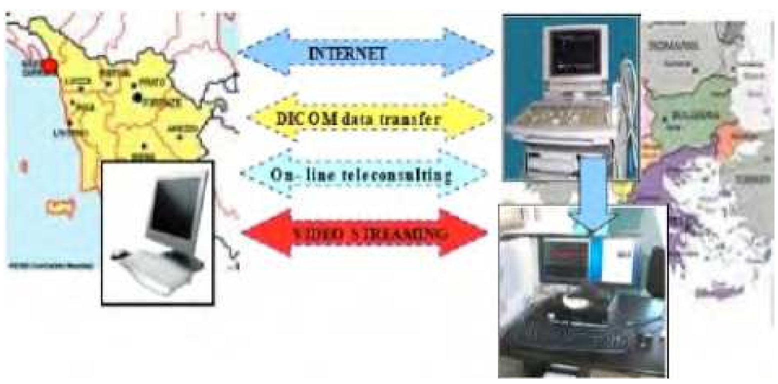



Fig. 15. Tele-consulting for collaborative diagnosis and care planning: diagnostic images are transferred via Internet (on-line or off-line) from remote clinical centers to the reference one.

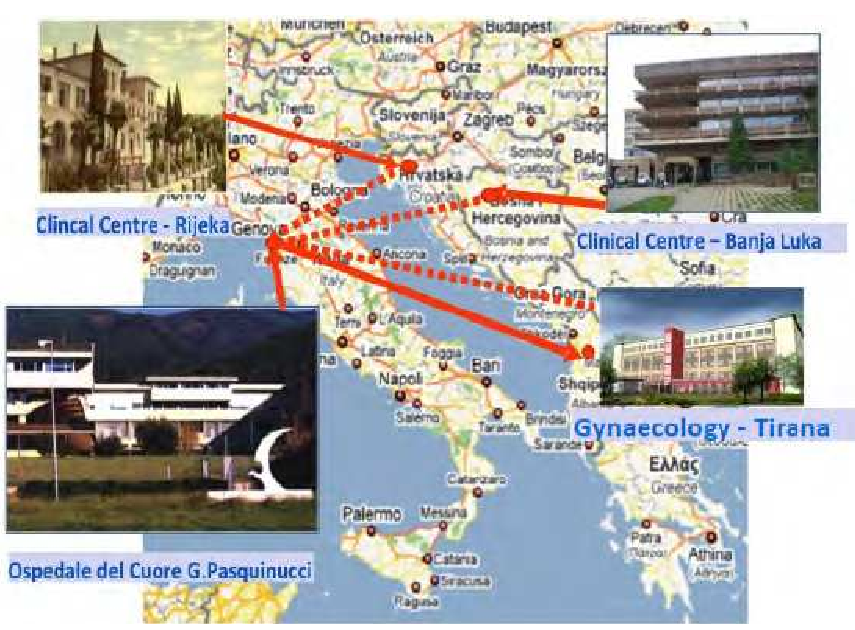



Fig. 16. Tele-consulting network between Massa Hospital and Balkan Centers

Tele-echocardiography was initially implemented in pediatric centers of Banja Luka and Rijeka and Gynecology University Hospital in Tirana, using videoconferencing equipment for transmitting on-line over Internet sequences of diagnostic images. Limitations in terms of functionality, versatility, scalability and cost/effectiveness suggested exploitation of Open-Source technology to set up low-cost devices implementing both live and store-and-forward teleconsulting as well as videoconference and image storage/management.
These devices are generally prone to promote collaborative health-care in various medical fields even in remote Countries not able to acquire expensive medical technology.

## 9. Conclusion

While information systems for reporting diagnostic, clinical and cardiac surgery activities have been in use at GPH for more than ten years, since 2005, EMR is daily used on all the patients admitted in the clinical departments (Cardiology, Cardiac Surgery and ICU). In order to assure confidentiality, EMR access is allowed only to authorized health care personnel using a personal password to login.
So far at GPH in Massa more than 30000 inpatient and 240000 outpatient records were processed and archived, including up to 12000 cardiac surgery reports (adult and pediatric).
The HIS, developed by the efforts of interdisciplinary teams of IFC-CNR and GPH during the last fifteen years, despite initial difficulties, mainly due to adoption of new technology, was finally effective for both clinical and administrative management (Carpeggiani et al., 2008). Data integration and archiving allowed hospital personnel (physicians, nurses, secretary and administration officers, director) to access clinical records easily and reliably with benefits to overall health-care process. Particularly EMR in the ward promoted staff inter-communication and comprehensive documentation of patient care during hospitalization. Actually a series of technical measures, continuously updated, were needed for assuring data security, confidentiality and integrity, given the continuous exposure to intrusion risks on networks. Technical services were organized to provide 24-hour assistance and support.
Currently medical records need to be printed out after patient discharge and signed by the responsible of department, just achieving a legal value. Application (under development) of both electronic signature and official clinical data storage systems, according to regulatory laws, will allow to authenticate electronic documents achieving a real paperless medical record. Policies for data access, backup and storage will be revised and updated.
Adoption of standard dataset for the characterization of cardiac patients was crucial to achieve comprehensive registers allowing to benchmark surgeons' practice by making prospective prediction of patient outcome according to multicenter risk stratification models. Uploading pediatric cardiac surgery records on international EACTS database it was possible to qualify the GPH centre as one of the best ones in terms of outcome during the last years.
Actually revision of both database architectures (Oracle DBMS) and clinical applications according to health-care data exchange standards (HL7 v3, IHE) (HL7 standard) is currently under development aimed at improving performance of information systems, safeguarding their security and also to assure multicenter interoperability.

## 10. Acknowledgment

We thank the information technology teams of both Heart Hospital in Massa (Andrea Gori, Emiliano Rocca, Giacomo Piccini and Tiziano Carducci) and of Hospital section in Pisa

(Alessio Ciregia, Mario Cossu, Mauro Raciti, Cristina Salvatori, Andrea Trabucco, Fabrizio Conforti, Giuseppe Di Guglielmo, Gavino Marras) for help, suggestions and advice in setting up applications. Moreover our appreciation for collaborative efforts and suggestions to the clinical staff involved in cardiology, cardiac surgery, anesthesia and radiology (particularly Bruno Murzi, Nadia Assanta, Sergio Berti, Paolo Del Sarto, Mattia Glauber, Dante Chiappino, Pierantonio Furfori and Umberto Paradossi).

## 11. References

Carpeggiani, C.; Dalmiani, S.; Taddei, A.; Macerata, A.; Franchi, D.; Michelassi, C.; Chelozzi, L.; Emdin, M.; Benassi, A. & L'Abbate, A. (2000). Use of an electronic medical record in a department of Cardiology. In: *Computers in Cardiology*, vol.27, pp. 291-294, IEEE.

Carpeggiani, C.; Macerata, A.; Taddei, A,; Benassi, A. & Donato, L. (2008). Sviluppo, applicazione e valutazione di un sistema integrato gestionale e clinico nel campo delle malattie cardiovascolari: dieci anni di esperienza. *G Ital Cardiol*, vol. 9, pp. 558-565.

Cossu, M.; Furfori, P.; Taddei, A.; Mangione, M. & Del Sarto, P. (2011). Anesthesia Information Management System in Cardiac Surgery. In: *Proceedings of Computing in Cardiology*, Hangzhou, China, September, 2011.

Dalmiani, S.; Taddei, A.; Glauber, M. & Emdin, M. (2002). An informative system for structured data management to build a cardiological multidimensional database. In: *Computers in Cardiology*, vol.29, pp. 369-372, IEEE.

DCM4CHE. Available from:
http://www.dcm4che.org/

EACTS database. Available from:
http://www.eactscongenitaldb.org/

Gori, A.; Taddei, A.; Mota, D.; Rocca, E.; Carducci, T.; Piccini, G.; Ciregia, A.; Marcheschi, P.; Assanta, N.; Murzi, B. & Ricci, G. (2010). Open Source teleconsulting system for international cooperative medical decision making in congenital heart diseases. In: *Computing in Cardiology*, vol.37, pp. 481-484, IEEE.

HL7 standard. Available from: http://www.hl7.org/

Macerata, A.; Landucci, L. & al. (1995). Networking for health care administration and delivery: the information system at the CNR Institute of Clinical Physiology. *Proceedings of Health Telematics '95,* pp. 113-118, Pisa, Italy.

Mangione, M. BMF - Bio Medical Framework (2006). Technical Report, National Research Council, Institute of Clinical Physiology, Pisa, Italy.

OSIRIX. Available from:
http://www.osirix-viewer.com/

SICCH Database. Available from:
http://www.sicch.org/ sections/Database_Nazionale/index.html

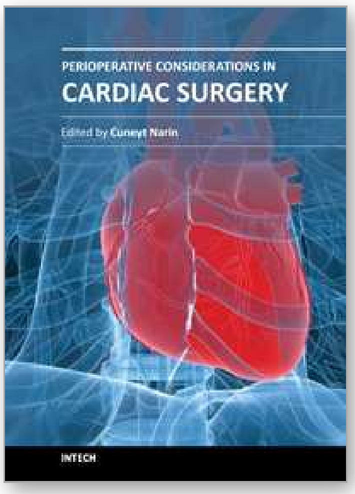
Taddei, A.; Dalmiani, S.; Piccini, G.; Vellani, A.; Carducci, T.; Buffa, M.; Scebba , L.; Glauber, M.; Murzi, B.; Biagini, A. & Macerata, A. (2003). Data integration in cardiac surgery and resource management. In: *Computers in Cardiology*, vol.30, pp. 279-282, IEEE

Taddei, A.; Fiaschi, A.; Kraft, G.; Fania, A.; Furfori, P.; Del Sarto, P. & Santoli, F. (2000). Integrated system for anesthesia records in cardiac surgery. In: *Computers in Cardiology*, vol.27, pp. 789-792, IEEE.

Taddei, A.; Pisani, P.; Vellani, A.; Dalmiani, S.; Piccini, G.; Carducci, T.; Kraft, G.; Rocca, E.; Storti, S.; Andrenelli, A.; Parri. M.S.; Cardillo, M.; Lauciello, P.; Gwynne, S. & Macerata, A. (2005). Laboratory Data Integration into Medical Record. In: *Computers in Cardiology*, vol.32, pp. 909-912, IEEE .

Taddei, A.; Dalmiani, S.; Vellani, A.; Rocca, E.; Piccini, G.; Carducci, T.; Gori, A.; Borghini, R.; Marcheschi, A.; Mazzarisi, A.; Salvatori, C. & Macerata, A. (2008). Data Integration in Cardiac Surgery Health Care Institution: Experience at G. Pasquinucci Heart Hospital. In: *Computers in Cardiology*, Vol.35, pp. 287−290, ISSN 0276−6574.

Taddei, A. (2011). How we set up telemedicine for diagnosis and care of heart defects in the foetus and newborn. In: E-journal of the ESC Council for Cardiology Practice, Vol.9, N°33. Available from: http://www.escardio.org/communities/councils/ccp/e-journal/volume9/Pages/telemedicine-open-source-technology-congenital-heart-disease-foetus-newborn-Alessandro-Taddei.aspx




**Perioperative Considerations in Cardiac Surgery**

Edited by Prof. Cuneyt Narin

ISBN 978-953-51-0147-5
Hard cover, 378 pages
**Publisher** InTech
**Published online** 29, February, 2012
**Published in print edition** February, 2012

This book considers mainly the current perioperative care, as well as progresses in new cardiac surgery technologies. Perioperative strategies and new technologies in the field of cardiac surgery will continue to contribute to improvements in postoperative outcomes and enable the cardiac surgical society to optimize surgical procedures. This book should prove to be a useful reference for trainees, senior surgeons and nurses in cardiac surgery, as well as anesthesiologists, perfusionists, and all the related health care workers who are involved in taking care of patients with heart disease which require surgical therapy. I hope these internationally cumulative and diligent efforts will provide patients undergoing cardiac surgery with meticulous perioperative care methods.