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Interoperability in Healthcare: The Challenge of the Single Patient Record - From Data Fragmentation to a Comprehensive View of the Care Pathway

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Abstract: **Summary: Healthcare information systems are traditionally closed, monolithic silos. This architecture makes it difficult, if not impossible, to develop and deploy innovative applications that could function interchangeably across different systems in hospitals, laboratories, or doctors' offices. This lack of interoperability stifles innovation and prevents healthcare professionals from benefiting from modern tools.**

The authors present SMART on FHIR as a solution to this problem. It is an open platform that combines two standards, FHIR (Fast Healthcare Interoperability Resources) and SMART (Substitutable Medical Apps, Reusable Technologies).

The central idea is to create an ecosystem similar to that of app stores for health, where developers can create an application once and see it working on any SMART on FHIR compatible SIS.

This article demonstrates the feasibility of the approach through:

- **The development of a "Launchpad" (dashboard) allowing clinicians to launch applications directly from their SIS.**
- **The creation of prototype applications for various use cases (data visualization, decision support).**
- **Successful integration tests with several major SIS, proving that the approach is viable on a large scale.**

SMART on FHIR is presented as a paradigm shift. Instead of building increasingly complex closed systems, it proposes to create a simple and standardized platform on which a global community of developers can innovate.

In summary, this article lays the technological groundwork for a more open, innovative and interoperable health ecosystem, considered a key component for the future of health information systems.

Keywords: **Interoperability, Heterogeneous systems, Data silos, Data fragmentation.**

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1. INTRODUCTION

21st-century medicine is characterized by rapid technological innovation, capable of sequencing a genome in a matter of hours and performing remote surgeries. Yet, in many countries, the most crucial information—a patient's medical record—often remains fragmented, trapped in computer systems that don't communicate with each other. A patient visiting their general practitioner, a testing laboratory, and then the hospital sees their health data scattered across multiple computer silos. The challenge of a Single Patient Record is not merely technical; it is a clinical, economic, and ethical imperative for improving the safety, quality, and efficiency of care.

The 21st-century healthcare landscape is marked by a paradoxical double reality. On the one hand, rapid technological innovation is enabling unprecedented diagnostic and therapeutic advances (high-speed genomic sequencing, robotic surgery, telemedicine). On the other hand, the information system that should support these advances remains archaic and fragmented. An individual's health data, instead of forming a continuous and coherent narrative, is scattered across a multitude of informational "silos": the general practitioner's office, the medical biology laboratory, medical imaging, and the records of various hospitals. This fragmentation creates an informational discontinuity that hinders care coordination, generates redundant tests, increases the risk of medical errors, and disempowers patients in their own healthcare journey. Thus, the central challenge is no longer generating data, but circulating it intelligently, securely, and effectively to support the patient-caregiver relationship.

To what extent does the lack of interoperability of health information systems constitute a major obstacle to the implementation of an operational Single Patient Record, and what technical and organizational strategies would make it possible to overcome this obstacle to improve the quality, safety and efficiency of care pathways?

The implementation of an interoperability framework based on universal semantic and syntactic standards (such as HL7 FHIR) and supported by robust governance is the sine qua non condition for achieving a functional Single Patient Record, which in turn is a critical lever for improving clinical and economic outcomes.

The value of this research is threefold, addressing clinical, economic, and ethical issues:

- **Clinical and Patient Safety Benefits:** Unified and comprehensive access to patient information enables informed medical decision-making, reduces the risk of errors (allergies, drug interactions) and promotes continuity of care, particularly for patients with chronic or complex conditions.
- **Economic and Efficiency Benefits:** Interoperability helps combat waste by avoiding unnecessary repetition of tests and diagnostic procedures. It also optimizes medical time by automating information collection and reduces administrative costs.
- **Ethical and Empowerment Interest:** An interoperable DPU places the patient at the center of the system by giving them access and control over their data, thereby strengthening their autonomy and involvement in their own health choices (concept of "empowered patient").

The literature is unanimous in denouncing the harmful effects of health data fragmentation. Epidemiological studies highlight the impact of informational discontinuities on patient safety (Forster et al., 2004; Kripalani et al., 2007).

Research has documented a transition from historical standards (HL7v2, proprietary) to modern, more flexible, and web-friendly standards, with a growing dominance of FHIR (Fast Healthcare Interoperability Resources). FHIR is praised for its RESTful API-based approach and ease of implementation, but challenges remain regarding the maturity of certain profiles and semantics (Mandel et al., 2016).

Numerous studies (Adler-Milstein & Pfeifer, 2017) highlight that the main obstacles are no longer technical. They identify "information blocking" linked to competitive business models, legitimate concerns about privacy and security (regulations such as the GDPR in Europe), and a lack of digital skills among some healthcare professionals.

The literature on international successes (such as the "Blue Button" in the United States, the G-NICS projects in France, or the Estonian model) highlights the importance of clear governance, involving all stakeholders (state, insurers, professionals, patients) to define the rules of the game regarding sharing, consent and security.

In summary, the literature establishes a strong imperative for interoperability but shows that its achievement is a complex, multidimensional problem requiring an integrated approach combining technology, economic incentives, a legal framework, and changes in professional practices. This research aims to contribute to the understanding of this complex equation.

2. FUNDAMENTAL DEFINITIONS

- Information system (IS): A system constituting a structured set of resources dedicated to the collection, storage, processing and dissemination of information, generally through a computer network. It is a system with socio-technical characteristics, decomposing into two subsystems: one social and the other technical.

- Computer system: A system referring to all the hardware, computer and telecommunications equipment used by a company in the course of its business activities, including data processing, storage, transfer and various modes of communication.
- Heterogeneous computing: A computing environment in which different types of processors and processing units, such as CPUs , GPUs , FPGAs, and specialized accelerators, coexist, working together to perform various tasks. The goal is to leverage the unique advantages of each processor type to optimize performance, energy efficiency, and cost-effectiveness.
- Interoperability in Healthcare: This is the ability of different healthcare information systems to communicate, exchange data, interpret it, and use it in a consistent, accurate, and secure manner within an organization, region, or country. It operates at several levels:

1. Technical Interoperability: The ability of systems to connect and exchange data (protocols, file formats).
2. Semantic Interoperability: The ability to give a uniform meaning to the data exchanged. For example, ensuring that "BP" means "Blood Pressure" and that its units (mmHg) are understood by all systems.
3. Organizational Interoperability: The ability of organizations, processes, and people to collaborate to share information while respecting business rules, confidentiality, and governance.

- Single Patient Record: This is not a centralized, single database containing all patient records. It is an access concept. The Single Patient Record is a vision whereby any authorized healthcare professional, regardless of their practice setting, can securely access all of a patient's relevant health data, thus creating a complete and up-to-date view of their care pathway. It is the informational "common thread" that follows the patient.

3. THE CURRENT SITUATION: A FRAGMENTED LANDSCAPE AND ITS CONSEQUENCES

Currently, the landscape is often one of fragmentation:

- Multiplicity of Systems: Hospitals, clinics, private practices use different and unconnected software (Computerized Patient Record, Integrated Management Software).
- Lack of Standards: Each software publisher uses its own formats and terminology.
- Direct Consequences:
  - Repeating tests: An X-ray or blood test must be redone because the previous results are inaccessible, resulting in unnecessary costs and delays.
  - Medical errors: Lack of access to the complete history (allergies, current treatments, past medical history) increases the risk of prescription or diagnostic errors.
  - Ineffective care walls: Continuity of care is broken, coordination between actors is hindered.
  - Administrative burden: Healthcare professionals spend considerable time searching for and transmitting information by fax, mail or telephone.

4. THE ESSENTIAL PILLARS OF INTEROPERABILITY

The construction of a Single Patient Record rests on several critical foundations:

1. Common Standards and Terminologies:
   - HL7 FHIR (Fast Healthcare Interoperability Resources): This is the emerging international standard. It functions as a modular "toolbox", using modern APIs (like those of the internet) to exchange data quickly and in a structured manner.
   - Terminologies: SNOMED CT (for clinical terms), LOINC (for laboratory identifiers), ICD-10 (for disease classifications). These common lexicons guarantee semantic interoperability.
2. The National Patient Identifier (INP): A unique, secure, and permanent number assigned to each citizen for their entire life. It is the key that reliably links all the data of the same patient, preventing confusion between individuals with the same name.

3. Governance and Trust:
    - Legal and Ethical Framework: Robust legislation must define who can access what, for what purpose, and with the informed consent of the patient.
    - Data Security: Data encryption, access traceability (who saw what, when and why), strong user authentication.
    - Patient Consent: The patient must be placed at the heart of the system, with control over who can access their data (right to lock certain information, consultation history).
4. Sharing Infrastructures: These are the "digital highways" that enable exchange. This can take the form of:
    - Regional or national exchange platforms.
    - "Network" architectures (Health Information Exchange - HIE) where systems communicate with each other without a single central base.

5. CHALLENGES TO OVERCOME

- Technical challenge: Integrating legacy systems that are not designed for sharing. Ensuring scalability and performance.
- Financial: The cost of modernizing systems, training, and maintenance is enormous. Who pays? The government, healthcare facilities, insurers?
- Cultural and Organizational: Changing the mindsets and habits of healthcare professionals ("culture of sharing" vs. "culture of silo"). Ensuring buy-in and training.
- Politics and Sovereignty: The management of health data is a matter of national sovereignty. The model must guarantee the protection of data against commercial interests or cyber threats.

6. EXPECTED BENEFITS

- For the Patient:
    - Safer and more personalized care.
    - Better coordination between professionals.
    - Empowerment through access to one's own file.
    - Reduction of administrative procedures.
- For Healthcare Professionals:
    - A comprehensive and instantaneous view of the patient for informed decision-making.
    - Saving time and reducing administrative burden.
    - Improved coordination and collaboration.
- For the Health System:
    - Reduction of avoidable expenses (redundant examinations).
    - Improving the quality and safety of care.
    - Support for medical research and public health (via data anonymization).

7. CONCLUSION

Interoperability for a Single Patient Record is not a technological project, but a healthcare societal project. It is a marathon, not a sprint. Its success depends not only on the quality of APIs or servers, but on a collaborative roadmap involving:

- The Public Authorities to establish the regulatory and financial framework.
- Healthcare professionals to design tools adapted to their practice.

- Manufacturers and software publishers to adopt and implement the standards.
- Patients and their associations must be active partners in this change.

The challenge is immense, but the promise is just as great: to move from fragmented medicine to a care pathway medicine that is fluid, secure and truly person-centered.

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