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POINT OF VIEW

Artificial intelligence and the Internet of Medical Things in the ICU: Time for implementation

Inteligencia artificial e *Internet of Medical Things* en UCI: momento de la implementación

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The technological revolution that is transforming society is centered on big data (large volume of data, variety of formats, immediate generation, processing and execution), machine learning (artificial intelligence algorithms with automatic learning and analysis) and multiple and massive sensorization — commonly referred to as the *Internet of Things* (automatic exchange of data between devices and servers).

In the case of Intensive Care, the implementation of all these technological potentials has just begun.[1] Even though the mentioned technology is readily available (there are multiple open source language libraries such as Python), easy to use (even for technological career students) and inexpensive, Intensive Care Units (ICUs) throughout the world continue to manually perform tasks that could easily be automated. The possibilities for exploiting the data generated by patients and physicians in that setting are enormous, with a view to developing more personalized medical care.[2,3]

As a practical example, a recent publication by our group proposes the implementation of an intelligent urinometer for the automatic measurement of urine flow in catheterized patients.[4] Based on an infrared sensorization system fitted to a standard drip before the urine collecting bag, we can measure the number of urine drops generated per minute, and thus estimate diuresis in real time. The device is equipped with an alarm system for detecting oliguria, anuria or even minor changes in urine flow pattern, individualized to each patient. In addition, it includes a colorimeter for the real-time measurement of urine color — thus allowing precise and early detection of hematuria or jaundice, among

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other disease conditions. All this information is automatically entered into the clinical information systems through LoRa communication. The production cost is estimated to be less than 50€, with no added expenses related to consumables or disposable elements.

Everything appears to indicate that the use of the Internet of Medical Things (IoMT), with its ''data harvesting'' philosophy, together with machine learning and big data techniques, will change the technological paradigm in ICUs.

Key elements in this transformation:

1. The time for implementation has come. The technology is already available. No major new technological developments are to be expected or are necessary. What we do expect is that the implementation of these tools will cover the reality and the needs of ICUs, radically transforming clinical practice.
2. The technology is accessible and easy to use. Often through open-source applications or languages (e.g., Python), and generally at low cost. This applies to both the new sensors that are appearing on the market and to the available in-the-cloud commercial services, needed for real-time connectivity.
3. It is essential for the work teams to incorporate technical professionals who understand the reality of our ICUs. Many developed commercial products are useless because they have been developed by engineers without taking into account the reality of the intensive care setting. Thus, as a starting point, healthcare professionals must define the question or problem to be solved, after which the engineers will apply their knowledge to answer these specific needs (and not others, or for generating new needs for mere commercial reasons).
4. Great care is required in relation to the external validity of the machine learning algorithms, with serious overadjustment problems. In other words, precision medicine solutions may be valid for the training population involved, but not for patients from another country, or of another race or culture. This may come into conflict with the scaled rapid and massive business model (blitzscaling) typical of large technological companies, and which is one of the reasons why the technological revolution has not yet reached the healthcare setting on a massive scale. However, nothing impedes the development of high-value local solutions developed by local teams and with smaller-scale commercial value.
5. The information obtained and analyzed must be processed with a clinical sense; the participation of healthcare professionals in this development is therefore essential. Delivery of the information must be managed using clinical decision support systems (CDSS) that facilitate the obtaining of information and decision-making without added costs for the healthcare professionals in terms of time or effort.

The implementation of open-source clinical technology (hardware/software) and the creation of expert committees to guarantee patient safety may be an effective way to address certain limitations in medical care. The central focus of the entire system must be patient safety.

The main limitations of this transformation include:

1. A lack of technological knowledge on the part of clinicians who are unaware of the possibilities offered, the limitations (which are sometimes particularly important) of the machine learning algorithms, and shortcomings in terms of understanding with the engineers.
2. Regulatory barriers which, while necessary for patient safety, slow down and increase the costs of local developments to the point where they sometimes prove unfeasible.
3. The false expectation that the implementation of this technology will come from the major technological companies that are more conditioned by the need for large and rapid profit returns for their shareholders than by the development of solutions suited to the healthcare system. In this regard, it seems natural to seek collaboration among hospitals, universities and companies interested (as stakeholders) in the development of applications and practical solutions, beyond basic or theoretical research.
4. Although most ICUs currently have electronic medical records, and many of them are directly integrated with monitoring systems such as ventilators, hemofiltration systems, etc., almost none of these Units feature a system allowing the real-time use of these data in combination with artificial intelligence algorithms and sensors to optimize the clinical decision support systems. This is a fundamental step for implementing IoMT in our daily activities as intensivists. Apart from the different means for establishing the physical connection according to the suitability of the setting or application, such as WiFi, Bluetooth or LoRa, in the clinical setting most device brands have successfully chosen the HL7 protocol for data exchange between the different devices and the medical records software. In its truly improved latest versions, the HL7 protocol is an open-source data exchange tool, and is a clear indication that the sector is focusing value on issues other than data property and is moving towards the possibility of intercommunication between different brands and technologies. The HL7 protocol allows this to be done in an orderly manner. Another issue is to ensure that the applications allow easy inclusion of the use of any sensor rapidly and simply, based on configuration tools, and without having to program a new driver or perform integration with another electronic application.

In sum, the implementation of new technologies will resolve local problems with local solutions. This implies the incorporation of technological profiles into our usual work teams, where we all speak both languages: clinical and technological. In this context, we must bear in mind that the starting point of these developments is represented by the clinical needs, and that the ultimate objective is the integration of these solutions in our routine clinical processes — contributing value to the clinical work through increased efficiency and added clinical value.

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Conflict of interests

The authors declare that they have no conflict of interest.

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