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THE ACTIVITY OF THE ROBOT-ASSISTED SURGERY GROUP AT KU LEUVEN AS AN EXAMPLE OF SMART HEALTHCARE IN SMART CITY LEUVEN

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Abstract: This paper aims to investigate the issue of smart healthcare in Smart City Leuven using an example of the Robot-Assisted Surgery (RAS) group working at KU Leuven. The author sets the main research question (MRQ) "Do surgery robotics, represented by the RAS group, contribute to smart healthcare in Smart City Leuven?" and three supportive research questions (RQs): (1) Could we consider surgery robotics as a part of the concepts of a smart city and smart healthcare? (2) What is the specific nature of Smart City Leuven and its smart healthcare? (3) What is the activity of the RAS group? Respectively, this article is divided on the following three sections: the first part sets a theoretical background explaining the concept of smart city and the idea of smart healthcare; the second section presents Smart City Leuven and its key institutions in the area of healthcare system; the final part concentrates on the work of RAS group and its ongoing projects FAROS, ARTERY, and GIFT-Surg. Methodology of this article is based on literature review, research of internet sources, and a scientific interview with the Head of RAS group – Prof. Emmanuel Vander Poorten. Added value of this research is the discussion on the relevance of surgical robotics to the concept of smart healthcare by using the example of KU Leuven-based RAS group and Smart City Leuven.
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Keywords: REINITIALISE project, KU Leuven, Smart City Leuven, Robot-Assisted Surgery group, smart city, smart healthcare, surgical robotics

Tytuł: Działalność Grupy Robotyki Chirurgicznej na Katolickim Uniwersytecie w Leuven jako przykład inteligentnej opieki zdrowotnej w Inteligentnym Mieście Leuven
Streszczenie: Niniejszy artykuł ma na celu zbadanie kwestii inteligentnej opieki zdrowotnej w inteligentnym mieście Leuven na przykładzie Grupy Robotyki Chirurgicznej (GRC) działającej na Katolickim Uniwersytecie w Leuven. Autor stawia główne pytanie badawcze (GPB): „Czy robotyka chirurgiczna, reprezentowana przez GRC, przyczynia się do inteligentnej opieki zdrowotnej w inteligentnym mieście Leuven?", a także trzy pomocnicze pytania badawcze (PB): (1) Czy robotykę chirurgiczną można uznać za część koncepcji inteligentnego miasta i inteligentnej opieki zdrowotnej? (2) Jaka jest specyfika inteligentnego miasta Leuven i jego systemu inteligentnej opieki zdrowotnej? (3) Na czym polega działalność GRC?
Odpowiednio, niniejsze opracowanie zostało podzielone na trzy części: w pierwszej przedstawiono podstawy teoretyczne dotyczące koncepcji inteligentnego miasta i idei inteligentnej opieki zdrowotnej; w drugiej opisano inteligentne miasto Leuven oraz jego kluczowe instytucje funkcjonujące w obszarze systemu opieki zdrowotnej; trzecia część koncentruje się na działalności GRC i jej bieżących projektach: FAROS, ARTERY i GIFT-Surg. Metodologia artykułu obejmuje przegląd literatury, analizę źródeł internetowych oraz wywiad naukowy z kierownikiem GRC – prof. Emmanuelem Vanderem Poortenem. Wartością dodaną badań jest dyskusja na temat znaczenia robotyki chirurgicznej dla koncepcji inteligentnej opieki zdrowotnej, przedstawiona na przykładzie GRC na Katolickim Uniwersytecie w Leuven.
Artykuł został napisany przez Liliię Hrytsai, uczestniczącą jako początkująca badaczka w prestiżowym międzynarodowym projekcie REINITIALISE „Zachowanie podstawowych praw w korzystaniu z technologii cyfrowych w usługach e-zdrowia", finansowanym z programu Komisji Europejskiej Horyzont 2020 w ramach umowy o dotację nr 952357. Autorka serdecznie dziękuje koordynatorom projektu REINITIALISE za możliwość udziału w przedsięwzięciu, prof. Emmanuelowi Vanderowi Poortenowi za udział w wywiadzie naukowym i podzielenie się informacjami o GRC oraz szczególnie prof. Helderowi De Schutterowi za opiekę naukową podczas jej dwumiesięcznego (czerwiec–lipiec 2022) pobytu badawczego w Leuven w Belgii
Słowa kluczowe: projekt REINITIALISE, Katolicki Uniwersytet w Leuven, Inteligentne Miasto Leuven, Grupa Robotyki Chirurgicznej, inteligentne miasto, inteligentna opieka zdrowotna, robotyka chirurgiczna

INTRODUCTION

In academic literature there is no consensus regarding the definition of smart city. Many scholars link a smart city with remarkable attributes, such as application of information and communication technology (ICT), use of internet of things (IoT), digitalisation and so on. The European Commission defines the phenomenon of smart city as *"a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business"*, when at the same time underlines that *"a smart city goes beyond the use of digital technologies for better resource use and less emissions"*, which results in upgraded waste disposal and water supply facilities, smarter urban transport systems, more efficient solutions to heat and light buildings, safer public spaces, a more responsive and interactive city governance, and a better addressing the needs of an ageing population (European Commission 2022).

In the smart city system, smart healthcare constitutes an essential element, on which put a special emphasis in this article. While many scholars entirely focus on digitalisation of smart healthcare, their opponents advocate for its broader meaning, which would cover artificial intelligence (AI), robotics and other healthcare innovations. Since the case study in this paper is the KU Leuven based Robot-Assisted Surgery (RAS) group, which deals with a creation of innovative surgery robots, it is essential to come to an agreement whether surgery robotics are a part of smart healthcare or not. Thus, the main research question of this article is "do contemporary surgery robotics, presented by the RAS group, constitute a pillar of smart healthcare in Smart City Leuven?" To answer this question, we need to examine three important elements – the place of robotic surgery in the concepts of a smart healthcare and smart city; smart healthcare in Smart City Leuven; and the activity of the RAS group.

The intention to transform Leuven into a smart city was adopted on 23 October 2017 by a Leuven's Triple Helix – government, university and industry. It is important to remember that many cities create their own definition of a smart city and, in its strategy, the City Council of Leuven defined a smart city as a *"a futureproof liveable urban setting for inhabitants and city visitors with specific attention for social inclusion"*. Also, Smart City Leuven identifies its five key domains for smart development: (1) optimisation of streams; (2) smart service delivery; (3) smart health(care); (4) city experience; and (5) talent. Thus, under the definition of a smart city provided by Leuven, smart healthcare (as a part of Smart City Leuven) should not be narrowed to IoT and ICT, but can include smart healthcare solutions. This approach is supported by the promotion of world-class healthcare innovations in areas beyond IoT and ICT, as a part of the Leuven Innovation Region and the Leuven MindGate (Heijlen & Joep Crompvoets 2019: 83-85).

The most suitable word describing activity of the Robot-Assisted Surgery group in the area of healthcare is 'innovative'. Based at KU Leuven, the RAS group provides a tight collaboration with UZ Leuven, which resulted in numerous groundbreaking inventions, e.g., the Vesalius Robot. Searching for opportunities to support surgeons in their responsible and unimaginably hard work, the RAS group in cooperation with high-class research institutions works in a number of projects, i.e., Horizon-funded projects FAROS (Functionally Accurate RObotic Surgery) and ARTERY (Robotics and AI to revolutionise interventional cardiology), as well as GIFT-Surg (Guided Instrumentation for Fetal Therapy and Surgery).

Summarizing, this elaboration is focused on the main research question (MRQ): "Do surgery robotics, presented by the RAS group, contribute to smart healthcare

in Smart City Leuven?" and three supportive research questions (RQ1), (RQ2) and (RQ3):

- **RQ1:** Could we consider robotic surgery as a part of the concepts of a smart city and smart healthcare?
- **RQ2:** What is the specific nature of Smart City Leuven and its smart healthcare?
- **RQ3:** What is the activity of the RAS group?

This research is constituted from the three sections: the first part explains the phenomena of smart city and smart healthcare; the following section presents Smart City Leuven and its healthcare actors; and the final part aims to bring closer the activity and greatest achievements of RAS group. Methodology of this research is based on a desk review of relevant literature and internet sources, as well as a scientific interview with Prof. Emmanuel Vander Poorten, who is the Head of RAS group.

THE CONCEPTS OF A SMART CITY AND SMART HEALTHCARE

In the last three decades the idea of smart city has gained more popularity in international policies, local strategies and scientific literature. To begin the evaluation of the concept, it is essential to appreciate the growing role of cities in the future of our planet. The key reason seems be strongly connected to the prime role of urban areas in the economic and social aspects of people globally, and in the enormous impact on environmental sustainability (Albino et al. 2015: 1724). As of 2023, over 50% of the global population is urbanised. It is estimated that by 2050 this number will increase to about 70%, and by 2080 almost 80% of the world's population or 9 billion people will live in cities (HSBC Centre of Sustainable Finance 2019: 4). In 2019 report, HSBC Centre of Sustainable Finance states that cities are responsible for over 80% of global GDP, when at the same time they produce 70% of the world's GHG emissions (ibid.). Other sources claim that despite covering 3% of the planet's surface, urban areas consume up to 80% of the world's energy and emit 75% of the global CO_2 (Zellerbach-Adams 2023).

When we start to read and compare different sources about smart city, the first notable thing is authors' remarks regarding the absence of one consistent and clear definition of smart city among both practitioners and academia. Authors in their elaborations try to present different perspectives of what a smart city is and what its main attributes and elements are. For instance, Moura & de Abreu e Silva in their research provide the smart city definition created by the British Standards

Institute that states: *"the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens"* (Moura & de Abreu e Silva 2019: 1). In addition, they provide an alternative definition of smart city that can be understand as *"urban area (...) that uses electronic data collection sensors located in infrastructures, buildings, vehicles, institutions, and devices (IoT, Internet of Things) to supply real-time information of the main cities' operating systems"* (ibid.). Following, Moura & de Abreu e Silva underline the role of information and communication technology (ICT) in integration of all collected data from a number of urban systems, including water and energy supply, transportation, waste and sewage management and so on, into a single platform that allow local decision-makers to optimise the efficiency and increase the resilience of the city, as well as communicate and connect to its stakeholders (ibid.).

Table 1: Smart city dimensions

Dimension	Elements
Smart economy	Efficient energy use; green and circular economy; innovations; economic impact and return on investment.
Smart mobility	Intelligent transportation and transport systems; traffic management; intelligent parking; mobility as a service (MaaS).
Smart environment	Water and waste management; sustainable processes and urbanisation; monitoring of environmental indicators; hybrid approaches to manufacturing.
Smart people	Connected city residents, workers and visitors; e-learning; e-health/smart healthcare.
Smart living	Public security and urban resiliency; advanced materials; smart spaces.
Smart governance	Citizen participation; open data; digital automation of processes.

Source: Moura & de Abreu e Silva 2019: 4.

As mentioned earlier, a smart city covers all the elements of urban life and therefore has been seen, in many cases, as a panacea to address urban challenges, such as city growth, air and noise pollution, car traffic, energy consumption, etc. Naturally, the supporters of smart city consider this concept as a key to ensure efficient services and governance, to provide better educational and economic opportunities, as well as to improve social equity, i.e., by using digital technologies to support communication between city stakeholders. Apart from technical advantages provided by smart city, the idea to live in a city labelling itself as a 'smart' is usually viewed as being attractive for young, educated population. Thus, city promotion is considered as a strong element aiming to gain as many as possible high-skilled workers that play a significant role as drivers of economic growth in

urban areas (ibid.). Table 1 presents a comprehensive smart city model that offers its solution in a following six dimensions: economy, mobility, environment, people, living, and governance.

In a category 'smart people' we can notice the element of e-health. Similar to the concept of smart city, the phenomenon of e-health or smart healthcare is not precisely defined. The World Health Organization (WHO) defines e-health as *"the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research"* (World Health Organization). Tian et al. defines the idea of smart healthcare as *"a health service system that uses technology such as wearable devices, IoT, and mobile internet to dynamically access information, connect people, materials and institutions related to healthcare, and then actively manages and responds to medical ecosystem needs in an intelligent manner"*.

Smart healthcare involves multiple stakeholders, such as medical doctors, hospitals, patients and research institutions, as well as comprehensively covers various dimensions, i.e., disease monitoring and prevention, diagnosis and treatment, health decision-making, hospital management and medical research. For example, patients can use wearable devices to monitor their health and seek medical assistance via virtual tools; doctors can involve smart technology to improve diagnosis and increase effectiveness of information management; scientific research institutions can use machine learning instead of manual drug screening and to find suitable topics using big data. Through the use of these technologies, smart healthcare can effectively reduce the risk and cost of medical procedures, promote cooperation and exchanges in different regions, improve the utilization efficiency of medical resources, push the development of self-service medical care and telemedicine, and ultimately make customized medical more available (Tian et al., 2019: 63).

We can observe an ongoing tendency, where the understanding of smart healthcare is not narrowed to IoT, big data, ICT, cloud computing, 5G and other digital elements, but it also covers AI, biotechnology, surgical robots and mixed reality technology. In opposition to traditional meaning of smart healthcare linked to digital technology, many scholars such as Denecke & Baudoin (Denecke & Baudoin 2019: 1-3), Wason et al. (Wason et al. 2019: 73-74) Rayan et al. (Rayan et al. 2021: 3-5) and Tian et al. (Tian et al., 2019: 62) believe that smart healthcare also include broadly-understood healthcare innovations, e.g., famous Da Vinci Surgical Robot, smart bandages, 3D-printed devices, CRISPR gene editing and so on (Ellerbeck 2013). In this approach, we can consider surgery robotics as a vital

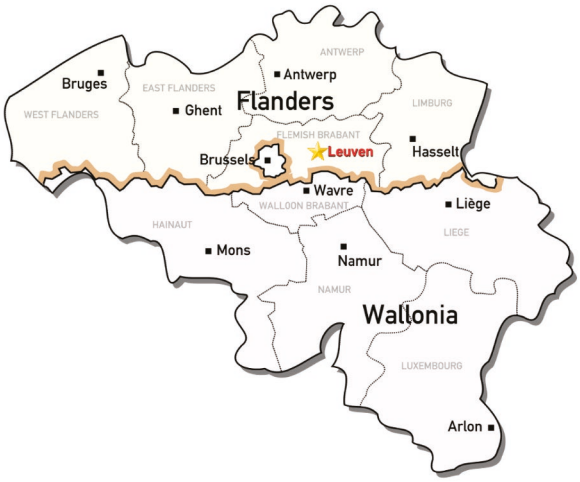
part of smart healthcare. Robotic surgery, also known as robot-assisted surgery, enables medical professionals to carry out a variety of intricate treatments with greater accuracy, adaptability, and control than is feasible with traditional methods. Robotic surgery is frequently related to minimally invasive surgery, which involves operations done through small incisions. It may also be used occasionally during various types of open surgery (Mayo Clinic 2023).

SMART CITY LEUVEN AND SMART HEALTHCARE IN THE CITY

Leuven (in French: *Louvain*) or (in German: *Löwen*) is the capital and biggest city of the province of Flemish Brabant in the Flanders Region – the Dutch-speaking northern region in Belgium. It lies along the Dyle River and is linked by a canal with the Scheldt River. With the area of 56.60 km², the city is situated around 26 km (16 mi) east of Brussels. Illustration 1 presents the unique central position of Leuven on a map of Belgium. The earliest mention of Leuven dates back to 891, when a Viking army was defeated by Arnulf of Carinthia – the Frankish king – in the Battle of Leuven. In the 15th century, a new golden era had begun for the City of Leuven with the founding of the oldest and largest university of the Low Countries[1] – the University of Leuven – in 1425 (Britannica 2023). As of 2022, the city population estimates 102,236 people (City population 2023), and, in addition, there are approximately 35,000 students, who live most time of an academic year in Leuven, but have their domicile in another place. This one-of-a-kind proportion between residents makes Leuven the largest student city in Belgium (Heijlen & Joep Crompvoets 2019: 87). During the last decades, Leuven has become a thriving global community with more than 170 nationalities from all around the world. In 2020, the city gained a title of the European Capital of Innovation (Varcities 2023).

[1] Low Countries or Benelux countries is a coastal region of northwestern Europe that includes Belgium, the Netherlands and Luxembourg.

Illustration 1: Map of Belgium



Source: Png Egg 2023.

The City of Leuven – a Belgium medium-size city characterised by almost 600-years academic tradition and world-famous research reputation – is seeking to become a smart city. On 23 October 2017, the City Council of Leuven has officially announced their intention to transform Leuven into a 'futureproofed smart city', which would be based on so-called Triple Helix model represented by government, university, and business. Before this symbolic event took place, the Smart City Leuven outlined its key goals and activities, as well as appointed a steering group and working group gathering representatives from the city administration, the city hall, the socio-economic development organisation MindGate, the companies Cronos and CommScope, and research institutions KU Leuven, Imec and UC Leuven-Limburg (Heijlen & Joep Crompvoets 2019: 83).

As mentioned earlier, academic literature does not provide with a common definition of a smart city. Generally speaking, it calls to urban innovations that manage urban challenges by applying modern ICT infrastructure and technologies, such as data platforms, sensors, cameras and big data analytics, and stakeholder participation. Many cities create their own definition of the smart city concept. For instance, Leuven recognises cities to become smart, when smart citizens, smart technology, and smart policy cooperate together. The aim of this cooperation is to establish a pleasant environment to work, to live, to learn and to relax. This ultimate goal for Smart City Leuven is concluded as *"a futureproof liveable*

urban setting for inhabitants and city visitors with specific attention for social inclusion." (ibid.).

As there is no 'one-size-fits-all' format for smart cities, the definition of Smart City Leuven is built upon, on the one hand, the cities' authentic advantages and, on the other hand, its specific challenges. The unique advantages of Leuven include its compact city centre and central location in Belgium, as well as the presence of world-class research institutions and large student population. In 2022, KU Leuven is ranked 42nd in THE World University Rankings (KU Leuven, Faculty of Economics and Business 2023). In its turn, specific challenges in Leuven encompass, for example, the desire to maintain city shopping attractive and data integration for the city government. Currently the Smart City Leuven has reached the phase of its implementation. Thus, the city administration is looking for efficient solutions to formalise the smart city organisation, to implement and expand projects, to coordinate smart city initiatives, and to monitor and assess performance and progress (Heijlen & Joep Crompvoets 2019: 83).

In order to improve the Smart City Leuven, the city administration created a range of plans that, on the one side, aiming to overcome current challenges, and on the other side, would solidly benefit to the further advancement of the local smart city. The first and foremost is the invention of Quadruple Helix model in Leuven, instead of beforementioned Triple Helix model. The ultimate idea of the Leuven city government is to incorporate in the present Triple Helix model – government, university, and business – the fourth element, mainly citizens. Thus, Leuven will get more citizen participation in public life of the city, as well as more stakeholders in its research and entrepreneur projects. Other plans for the development of Smart City Leuven encompass the following: (1) to add more financial stimuli for smart city projects; (2) to encourage businesses to contribute in making Leuven smarter; (3) to initiate a data governance framework for the city council; (4) to stimulate innovative practices, new task allocations and engagements inside the city administration; and (5) to realise social inclusion aspirations (ibid.).

The main inspiration behind the decision to choose a smart city vision for Leuven is rooted in the lack of coherence between ambitious plans regarding economic growth, innovative urban projects and the historical existence of Triple Helix model. Before the adoption of the smart city vision, the city of Leuven was well aware thanks to its experiments with road pricing, projects concerning district heating and Leuven's intentions to become climate neutral by 2030 (The European Commission's Intelligent Cities Challenge 2023). Nevertheless, as it was mentioned before all these projects lacked the coherence. In order to avoid the blind copy of the smart city trend, Leuven has decided to create its own coherent

model of smart city bringing together partners from the city government, university, research institutions, and business (Heijlen & Joep Crompvoets 2019: 85).

The city of Leuven and KU Leuven have already a long tradition of cooperation. Being a small city, short channels of communication between the city government and Leuven's stakeholders are established to support common interests. In 2016, this resulted in the founding of a socioeconomic development organisation named Leuven MindGate, which aims to enforce, consolidate and promote Leuven as a one of the world's leading regions for high tech, health and creativity. The participants of this organisation include all elements of the Leuven's Triple Helix model – government, industry and knowledge institutions. Taking into consideration these structural and historical partnerships among knowledge institutions, corporations and the city, Leuven MindGate represents the perfect ecosystem to create and realise a smart city vision of Leuven that focuses on its urban challenges and benefits the development of futureproof city innovations (Leuven MindGate 2022).

The members of Smart City Leuven highlight five focus areas for smart development that, on the one side, integrate existing initiatives, e.g., the priority sectors of Leuven MindGate, mainly high tech, health and creativity, and on the other side, introduce new subjects related, for example, to the inclusion of vulnerable and citizen participation (Heijlen & Joep Crompvoets 2019: 86). Table 2 demonstrates the Smart City Leuven five focus domains framing smart city projects in Leuven.

The Leuven Innovation Region is a European knowledge economy leader with a strong track record in health, high tech and creativity. One of the key focus areas of the Leuven Innovation Region is a pioneering and use of healthcare. Nowadays, Leuven is a place of world-class and breaking-ground healthcare and medical research. The roots of such a success are lying into the city's rich tradition of health and medical sciences. Starting from Andreas Vesalius – the graduate of University of Leuven and the father of modern anatomy in the 16th century – and up to the discovery of the first cochlear hearing aids and first HIV medical treatments in Leuven (Leuven MindGate).

The city of Leuven is a place of multiple public and private institutions focusing on healthcare research. The further research provides an overview of the most important Leuven's healthcare frontrunners, including UZ Leuven, the Rega Institute, imec, VIB, Health House, Mission Lucidity and other Leuven-based health tech companies. In total, these institutions give jobs to 22.000 people and their annual R&D budget estimates €1 billion. The Gemma Frisius Fund – a seed fund that receives €80 in investment from industry for every euro spent by the university – is a noteworthy illustration of KU Leuven's ability to attract resources (ibid.).

Table 2: Five focus domains of Smart City Leuven

Focus domain	Activities
Optimisation of streams	Leuven intends to optimise by 2030 mobility streams, such as human transport and distribution of goods, as well as energy streams concerning electricity, gas, warmth and water. This requires proficient and reliable information streams.
Smart service delivery	By using IT-capacity and smart processes, which make possible city data sharing, Leuven wants to fulfil the needs of inhabitants and city guests with specific emphasis on social inclusion.
Smart healthcare	Thanks to the presence of globally renowned healthcare actors in Leuven, the city plays a role of an ideal platform for inventing new healthcare technologies.
City experience	Targeted on a pleasant urban environment, the city of Leuven applies new technologies to improve social cohesion and empirical value for both inhabitants and city guests.
Talent	Leuven seeks to use the competences of its inhabitants taking into consideration each individual's talents, which on the one hand, attracts highly-skilled workers, which in its turn leads to the creation of urban innovations, and on the other hand, it promotes lifelong learning activities aiming to overcome a digital gap that divide inhabitants.

Source: Author's own elaboration on a basis of Heijlen & Joep Crompvoets 2019: 85.

Leuven – and Belgium as a whole – is also well regarded in terms of biomedical R&D, thanks in part to having the largest number of clinical tests per capita in the world. Researchers receive a great education, the equipment is cutting-edge, and the procedure for starting Phase I research is one of the quickest in Europe. Scientific institutions such as KU Leuven, VIB and imec place a considerable emphasis on biomedical research and development. They work with worldwide leaders in the pharmaceutical and healthcare industries and have established a number of spin-off firms with international appeal (ibid.). Table 3 presents the key stakeholders of the Leuven's healthcare development outlined at the official MindGate web page.

Table 3: Key stakeholders of the Leuven's healthcare development

Institution	Description
The University Hospital (UZ Leuven)	UZ Leuven is a Europe's second-largest academic hospital, bringing together education, scientific research and medical treatment. Innovation is essential for a university hospital. UZ Leuven has earned a top position in multiple areas, both in Belgium and globally, by consistently investing in research, innovative therapies, and cutting-edge technology. It is also a top-ranked clinical trial facility, having the quickest clinical trial approval rate in Europe. According to the American magazine Newsweek, UZ Leuven campus Gasthuisberg is one of the best hospitals in the world. UZ Leuven takes the 31st position in the Newsweek's ranking of the world's 200 best hospitals.
The Rega Institute for Medical Research	Founded in 1954 in Leuven, the Rega Institute is a biomedical research facility and is one of the few institutes in the world able to test thousands of molecules at high speed. The centre specialises in research on drugs against viral and bacterial infections. The institute developed a polio vaccine in the 1950s and gained world fame with its HIV inhibitor tenofovir. As for today, this drug is used by 20 of the total 35 million AIDS patients worldwide. The centre is also conducting research into antiviral medicines against the coronavirus.
Interuniversity Microelectronics Centre (imec)	As the Europe's largest independent nanoelectronics research centre, imec delivers the power of chip technology to the area of healthcare. Imec brings its expertise in technology and chip design to create innovative tools for pharma R&D, life sciences, therapeutics and surgery, clinical diagnostics, analytical biochemistry industries and biopharma production.
Flemish Institute for Biotechnology (VIB)	VIB is a world-class research institute. It constitutes a European Centre of Excellence in life sciences where about 1,500 top international scientists provide ground-breaking basic research. The primary activity of the institute is fundamental research in life sciences with the goal of finding practical applications for patients and society as a whole. Thus, VIB scientists in Leuven pushing the frontiers of what we know about molecular systems and how they govern living entities including humans, plants, animals and microorganisms. KU Leuven is home to three VIB research institutes spread across different campuses.
Health House	Health House is a one-of-a-kind platform that connects, informs and encourages healthcare innovation in an inspiring setting. In its Leuven facilities, Health House shows the future of healthcare based on scientifically confirmed information, as well as the influence technology will have on this future. Health House present AI, 4D-printing, VR, wearables and much more in a unique and engaging manner. Each visit to Health House is transformed into an amazing experience by leveraging the power of customisation, visualisation and digital storytelling.

Institution	Description
Mission Lucidity	As a world-class clinical, biomedical and nanotechnology R&D cluster, UZ Leuven, KU Leuven, imec and VIB are aiming to understand dementia and other neurodegenerative disorders with the goal of preventing or treating them. Together they accelerate medical research towards a future without neurodegeneration by using the biological, clinical, and technology expertise of the Leuven-based founding partners. In Mission Lucidity, they target neurodegenerative illness from many perspectives, zooming in on the cellular and intracellular levels with nanoscale technology, and studying disease processes and symptoms in humans.
Leuven-based health tech companies	The Leuven Innovation Region is the place to be for health tech start-ups and scale-ups. Several of the Leuven-based enterprises have worldwide appeal and are truly world leaders in health technology. For example, icometrix – a global leader in brain imaging AI; Materialise – a global leader in 3D printing that also medical gear production, Oxurion – a pioneer in the treatment of diabetic eye problems; Heilig Hart Hospital – a leader in quality care with patients as its centre focus; and Comate – a global player in mechatronics with a portfolio that includes many medical products.

Source: Author's own elaboration on the basis of Leuven MindGate 2022.

THE ACTIVITY OF THE ROBOT-ASSISTED SURGERY GROUP

The one stakeholder that is not clearly identified by the Leuven MindGate, but plays a pivotal role in Leuven's smart healthcare is KU Leuven, mainly the Robot-Assisted Surgery (RAS) group that has been producing innovation during the last 20 years. Founded in 2001, the RAS group constitutes a research team at the Mechanical Department of the KU Leuven. The group created by Prof. Hendrik Van Brussel, is currently steered by professors Emmanuel Vander Poorten, Joris De Schutter and Dominiek Reynaerts from PMA[2] for robot design, control, development and micromechanical issues and by Prof. Jos Vander Sloten from BMe[3] for the biomechanical expertise. The RAS group cooperates with UZ Leuven by performing clinical trials of their inventions, which later on are used by the hospital (KU Leuven, Robot-Assisted Surgery 2022a).

Since 2010, Emmanuel Vander Poorten, associate Professor of the Faculty of Engineering Technology of KU Leuven, has been the Head of RAS group at the Department of Mechanical Engineering. In 2000, he received the Mechanical

[2] The Division of Physics, Mathematics and Astronomy at KU Leuven.
[3] The Division of Biomechanics at KU Leuven.

Engineering degree from KU Leuven and, in 2007, he obtained the title of Doctor in Engineering from Kyoto University in Japan. Since his return to Belgium, he has played a significant role in a number of international projects involving surgical robotics and assistive technologies (FAROS 2021). During the elaboration of this research, the author conducted a scientific interview with Prof. Vander Poorten, who shared his opinion of the role of RAS group in the Leuven's healthcare system. He underlined that surgery robotics usually do not use IoT and ICT in their performance, however the group's recent research projects FAROS, ARTERY and GIFT-Surg are linked to AI elements.

According to the web page, the RAS group brings together 8 professors, 4 postdocs, 23 PhD candidates and 15 alumni from all around the world (KU Leuven, Robot-Assisted Surgery 2022b). The group works on eight key research topics, i.e., (1) Foetal surgery; (2) Eye surgery; (3) Spine surgery; (4) Robotic catheterization; (5) Virtual reality surgical training; (6) Haptics and tactile feedback; (7) Robotic laser surgery; and (8) Steerable instruments (KU Leuven, Robot-Assisted Surgery 2022c). Amongst the group's biggest scientific achievements is the implementation of 18 prestigious projects, including the Vesalius Robot – the first surgical robot that is on 100% invented, built and owned by KU Leuven. While the robot was invented by the Taiwanese Dr. Hsiao-Wei Tang, the driving force behind the project was Prof. Van Brussel – the founder of RAS group (KU Leuven 2023b). In the following part, the author investigates the group's three current research projects – FAROS, ARTERY and GIFT-Surg – that are performed within the prestigious international consortiums.

FAROS (Functionally Accurate Robotic Surgery) concentrates on the improvement of functional accuracy[4] incorporating physical intelligence in surgical robotics. Funded from Horizon 2020 for the period of 2021-2023 (now extended till 2024), FAROS brings together a consortium of five leading research institutions from four countries: KU Leuven (Belgium), King's College London (UK), University of Zurich (Switzerland), Sorbonne University and SpineGuard (France). By combining important non-visual senses, FAROS creates a functional depiction of the surgical task. Deep machine learning and AI are used in FAROS to evaluate intraoperative data and link accumulated knowledge to autonomously carry out surgical actions at operating rates considerably above the capacity of human response. The spine surgery procedure, where it is well known that pre-operative planning soon becomes dated and conventional sensors have thus far failed

[4] The degree to which the functional outcome of the surgery conforms to the expected value for a successful complication-free operation (functional objective).

to establish an accurate depiction of the scene, is used by FAROS to demonstrate this novel method of operating surgical robots (FAROS 2023).

ARTERY aims to apply robotics and AI to revolutionise interventional cardiology by creation of autonomous robotics (ARTERY 2023a). Also funded by EU Horizon (2021-2024), ARTERY is an initiative performed at international level in 4 countries by 7 partners: Politecnico di Milano (coordinator) in cooperation with Fondazione Politecnico di Milano, Scuola Superiore Sant'Anna, IRCCS San Raffaele Hospital and Artiness (Italy), KU Leuven and FBGS (Belgium), SwissVortex (Switzerland), and German partners (ARTERY 2023b). Cardiovascular disease (CDC) is a significant contributor to reduced quality of life, lost productivity, and increased healthcare expenditures. It is estimated that CDC costs the EU economy 210 billion euros annually (ARTERY 2023c). By using shared-autonomy robotic catheters, ARTERY creates a radiation-free method that encourages user engagement and easy interaction. The information produced by optical, electromagnetic, and echocardiographic sensing modalities is combined to give a better understanding of the cardiovascular environment (KU Leuven, Robot-Assisted Surgery 2022d).

GIFT-Surg (Guided Instrumentation for Fetal Therapy and Surgery) is led by London's Global University in collaboration with KU Leuven in Belgium, who work with doctors and surgeons at University College London Hospital NHS Trust, Great Ormond Street Hospital and UZ Leuven as part of a highly multidisciplinary team. Since 2014, the project has been receiving funding from Wellcome Trust[5]. In order to provide extremely accurate visualisation, both pre-operatively and in real-time, the GIFT-Surg team engineers a novel combination of cutting-edge interventional imaging systems and MRI/ultrasound scans. The surgeons use this in conjunction with cutting-edge surgical tools that offer new levels of flexibility and precision. Additionally, a training platform has been created to give surgeons the knowledge and expertise they need to treat congenital birth disorders such spina bifida and twin-to-twin transfusion syndrome (KU Leuven, Robot-Assisted Surgery 2022e).

CONCLUSION

Answering MRQ "*Do surgery robotics, represented by the RAS group, contribute to smart healthcare in Smart City Leuven?"*, the author highlights that the answer is strongly depends on the perception of the concepts of a smart city and smart healthcare. First of all, there is a no agreement on a common definition of

[5] A charitable foundation dedicated to health research based in London, UK.

neither 'smart city', nor 'smart healthcare'. During the elaboration of this research, the author comes to a conclusion that there is dual approach to the definition of smart healthcare. On the one side, defining smart healthcare, some scholars are strictly narrowed to the single element of digitalisation, IoT and ICT, while on the other side, an opposite group of researchers consider also the application of robotics, AI and other medical innovations as a pivotal part of smart healthcare. Answering the supportive RQ2, the Leuven's definition of a smart city – *"a future-reproof liveable urban setting* (…)*"*, as well as the Leuven MindGate's focus on multiple healthcare innovations and mixed actors, show that smart healthcare in the city of Leuven's perception is not narrowed only to digital technologies, but covers broad topics, i.e., surgery robotics. Finally, an answer to RQ3 provides us with overview of the activity of the RAS group, i.e., numerous research projects, surgery robotics inventions and their practical application at UZ Leuven. The high level of medical innovation offered by the group proves that their activity has a strong positive impact on smart healthcare in Leuven.

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