Institution: King's College London		
Unit of Assessment: UoA1		
Title of case study: Advancing robotic radical prostatectomy surgery in the UK		
Period when the underpinning research was undertaken: 2002 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Prokar Dasgupta	**Role(s) (e.g. job title):** Professor of Surgery	**Period(s) employed by submitting HEI:** 2002 – present
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

There are a number of invasive open surgeries associated with significant blood loss, excessive pain and a longer hospital stay, greatly affecting patients' health outcomes. These issues can be minimised through robotic surgery. King's College London researchers are regarded as pioneers in robotic surgery, particularly in urological cancers. Their work has transformed urology surgery in the UK through national uptake and training of robotic surgery through The Urology Foundation. They have developed the first international curriculum for safe training in robotic surgery and enabled Guy's Hospital to carry out most of the robotic surgery in the country (400 cases a year). King's research also showed better patient outcomes through robotic surgery and changed the programme of care for prostate cancer survivors to include support for the psychological effects of radical surgery. Additionally, King's demonstrated the cost effectiveness of robotic surgery, informing national guidelines in the UK and Canada.

2. Underpinning research

Prostate cancer is the most common male cancer: around 40,000 men are diagnosed with it each year in the UK alone. A standard radical prostatectomy – having the prostate removed – is a complex operation that has a high risk of men experiencing incontinence and impotence afterwards. Despite advances in non-surgical treatments such as radiation, chemotherapy and immunotherapy, surgery remains the cornerstone in the treatment of most solid cancers, including prostate cancer. Traditional open surgery is associated with greater blood loss, more pain and longer hospital stay compared to laparoscopic (keyhole) surgery – a minimally invasive alternative with a better prognosis for patients. However, developing proficiency in keyhole surgery involves a steep learning curve for surgeons, which many find difficult to overcome. King's has been at the forefront of a technology-aided alternative, robotic radical prostatectomy, that has evolved over the last 20 years to become the most effective and common form of surgery for prostate cancer in the UK. This work to refine robotic surgery in the context of urology has also led to progress in the application of robotic surgery in other clinical specialties.

King's pioneers robotic urology in the UK: In 2004, the urology team at King's established the use of the da Vinci Surgical System, powered by state-of-the art robotic technology. The da Vinci allows the surgeon to sit comfortably at a console that scales, filters and translates their skills into the precise movements of robotic micro-instruments within the operative site. It is equipped with a 3D vision camera rather than the 2D vision cameras of traditional keyhole surgery, with 10 times magnified vision, tremor filtration and wrist-like micro-instruments with 540-degree range of motion. Urologists led this multidisciplinary effort by mentoring colleagues from other areas in robotics sugery such as paediatrics surgery, thoracic surgery, transplantation and gynaecology.

King's researchers create new robotic tools to advance this procedure and other applications of robotic surgery: During robotic surgery the surgeon is not in direct contact with the patient and instead performs the surgery through the computer's console. In initial applications, there was a lack of a sense of "touch" throughout the process, affecting the accuracy of surgery

and increasing the risk of side effects. In 2005, King's academics, with colleagues at the engineering department, sought to change that by making use of haptic technology, which can create an experience of touch by applying forces, vibrations, or motions to the user and thus improving the practitioner's experience and surgical effectiveness. Since then, based on this technology, King's has contributed to the field of the robotic surgery through a number of ground-breaking developments:

- **Image guidance technique:** Displaying MRI images from the areas affected by cancer to be viewed through the console in the surgeon's direct line of vision while in surgery **(1)**.

- **3D model:** Using 3D printing to create an exact replica of the patient's prostate using images from an MRI scan and specialised software **(1)**. This allows surgeons to pinpoint exactly where the cancer is situated within the prostate, meaning they can plan in advance how to remove the cancer while preventing damage to important nerves nearby.

- **Octopus-inspired robotic arm:** Creating controllable-stiffness tools which enable the surgeon to temporarily collapse the device(s) during surgical procedures to provide the surgeon with improved views inside the body, or to use the tool(s) as a retraction aid **(2)**.

- **King's conducts the first-ever randomised trial of Telerobotics:** In 2002, King's conducted the first randomised controlled trial of robotic surgery with Johns Hopkins Hospital, USA. In this study they made use of Telerobotics, the area of robotics concerned with the control of semi-autonomous robots from a distance, chiefly using a Wireless network (Wi-Fi, Bluetooth, the Deep Space Network, and similar). They evaluated a robot's ability to use a robotic arm to accurately position and insert a needle into a kidney model to remove stones and compared it to traditional access with a human hand. Analysis of 300 procedures showed the robot to be more accurate than the human hand **(3)**.

- **Ultra-low latency 5G networking:** King's then went on to collaborate on work to improve the connectivity between robotic devices in different geographical locations. The 5G network, developed in partnership with telecommunications company Ericsson, allows the advanced robotic technology to operate with minimal delays between action and reaction, enabling a fully immersive experience in real time for users across the world and eliminating the perception of distance **(4)**.

Additionally, between 2012 and 2017, King's researchers used a Delphi process (structured interview method using a panel of experts) to develop the first standardized curriculum for training in robotic surgery **(5)**. Before this, there was no official structured learning for robotic surgery.

King's collaborative research provides the highest quality of evidence in robotic surgery: King's research led to the first ever randomized trial of open, laparoscopic (surgical diagnostic procedure to examine organs inside the abdomen) and robotic cystectomy (surgical removal of all or part of the urinary bladder). The trial was named CORAL (Clarification Open Robotic and Laparoscopic) after initial cohort studies comparing the three techniques **(6)**. CORAL found no difference in 90-day complication rates between traditional and robotic surgery, but it did confirm there were shorter hospital stays and less blood loss when surgery was performed through the robotic arm **(6)**.

3. References to the research

1. Sangpradit K, Liu H, **Dasgupta P**, Althoefer K, Seneviratne LD. Finite-element modeling of soft tissue rolling indentation. *IEEE Trans Biomed Eng*. 2011 Dec;58(12):3319-27. doi: 10.1109/TBME.2011.2106783.

2. Shafti A, Andorno F, Marchese N, Arolfo S, Aydin A, Elhage O, Noh Y, Wurdemann HA, Arezzo A, **Dasgupta P**, Althoefer K. Comfort and learnability assessment of a new soft robotic manipulator for minimally invasive surgery. *Conf Proc IEEE Eng Med Biol Soc*. 2015 Aug;2015:4861-4. doi: 10.1109/EMBC.2015.7319482.

3. Challacombe B, Patriciu A, Glass J, Aron M, Jarrett T, Kim F, Pinto P, Stoianovici D, Smeeton N, Tiptaft R, Kavoussi L, **Dasgupta P**. A randomized controlled trial of human versus robotic and

telerobotic access to the kidney as the first step in percutaneous nephrolithotomy. *Comput Aided Surg*. 2005 May;10(3):165-71. DOI: 10.3109/10929080500229561 4.

4. Kim SSY, Dohler M, **Dasgupta P**. The Internet of Skills: use of fifth-generation telecommunications, haptics and artificial intelligence in robotic surgery. *BJU Int*. 2018 Sep;122(3):356-358. doi: 10.1111/bju.14388

5. Volpe A, Ahmed K, **Dasgupta P**, Ficarra V, Novara G, van der Poel H, Mottrie A. Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. *Eur Urol*. 2015 Aug;68(2):292-9. doi: 10.1016/j.eururo.2014.10.025.

6. Khan MS, Gan C, Ahmed K, Ismail AF, Watkins J, Summers JA, Peacock JL, Rimington P, **Dasgupta P**. A Single-centre Early Phase Randomised Controlled Three-arm Trial of Open, Robotic, and Laparoscopic Radical Cystectomy (CORAL). *Eur Urol*. 2016 Apr;69(4):613-621. doi: 10.1016/j.eururo.2015.07.038

4. Details of the impact

Research by King's academics has made significant contributions to the rise of robotic surgery, particularly in the field of urology. The first Da Vinci system was installed in the UK in 2001. Now they are distributed in more than 70 NHS hospitals across the country **(A)**, with robotic assisted radical prostatectomy being its most common operation. Up to 5,000 radical prostatectomy operations are performed annually in the country, around 60% of which are executed with a robot **(B)**.

King's transformed urology surgery in the UK through national uptake and training of robotic surgery through The Urology Foundation (C). In the early 2000s, Professor Dasgupta was one of the only people in the UK to perform robotic surgery. Recognising his expertise, The Urology Foundation (TUF) – a charity created to provide more funding for urology research and training – funded Professor Dasgputa to travel around the UK to provide travel mentorship and training to urology surgeons.

Later in 2016, TUF made the decision to create a consortium of five TUF Centres of Robotic Training in the UK, of which King's – under Prof Dasgputa – was one. As part of the TUF Centres of Training consortium, King's trained 31 urologists in robotic surgery between 2016-2019, of which five completed 'mini fellowships' at Guy's Hospital and many more benefiting from the cascade training effect, and transforming the urological surgery landscape **(C)**. The CEO of TUF confirmed this work has been instrumental in transforming urological surgery in the UK: "*In a relatively short space of time – and with relatively modest funding – the majority of urological patients on the NHS now have access to robotic surgery by skilled robotic surgeons. 92% of prostatectomies, 82% of partial nephrectomies and 52% of cystectomies are now done robotically, meaning that the public are benefiting from this form of minimally invasive surgery and the improved outcomes.*"

"*The benefit to the public of TUF's robotic surgery training programme – and Prof Dasgupta's and KCL's role in this – is transformative and ground-breaking. In a relatively short space of time, we have opened access to the improved benefits of robotic urological surgery to the vast majority of NHS patients, and it is increasingly becoming the norm in many urological operations. The benefits to patients mean they recover faster and get back to their day-to-day lives quicker, and the economic benefit to the NHS of shorter bed stays in hospital are enormous.*" **(C)**

King's developed the first international curriculum for safe training in robotic surgery. Following publication in the British Journal of Urology International **(6)**, King's curriculum was validated in collaboration with the European Association of Urology Robotic Urology Section (ERUS) and has been adapted by a number of other surgical specialties as a gold standard training tool **(D.1)**. The curriculum was also adopted as the official guideline for training by the British Association of Urological Surgeons (BAUS) and King's researchers were invited to be part of its guideline panel members, essentially shaping the design of the document **(D.2)**. BAUS states

that the guideline is relevant to both experienced surgeons learning robotic skills and also to senior trainees learning robotic-assisted surgery anew. It reviews the skills required within robotics, discusses current training methods for robotic surgery and makes specific recommendations e.g. for modular training. The President of BAUS affirmed **(D.2)**: "*This paper is the first of its type and could be the model for training documents in other complex areas of urology.*" As of September 2019, there were a total of 1220 consultant urological surgeons and 337 trainees in the UK and Ireland **(D.3)**. 87.5% of the substantive consultants in the UK are BAUS members **(D.3)**.

King's expertise enabled Guy's Hospital (GSTT) to carry out most of the robotic surgery in the country, around 400 cases a year (B.3). The majority are prostate operations, but also include bladder and kidney surgery. The entire robotic programme carried out at GSTT was developed by Prof Dasgupta **(B.1)**. It is now the largest programme in the UK, training two full-time surgical fellows and more than 50 visiting surgeons a year **(B.4)**.

In July 2014, the success of Prof Dasgupta's work was recognised and GSTT received an international award of GBP600,000 from the Vattikuti Foundation (VF) to set up the Institute of Robotic Surgery, the only of its kind in the UK **(B.2)**. VF is a non-profit organisation committed to making robotic surgery cost effective and available to underprivileged communities. The CEO of VF said: "*Guy's and St Thomas' is the epicentre for urology robotic surgery in the UK, and has strong research and teaching programmes thanks to its links with King's College London and the Urology Foundation* **(B.3)**."

Since then, the Institute has trained three international fellows a year, many of whom have gone on to become independent robotic surgeons. It has led to >700 publications, device development, and the evaluation of new technologies for use in surgery such as Google Glass, Hololens and 3D printing of organs to guide surgery **(B.2)**.

King's research showed better patient outcomes through robotic surgery. The CORAL trial demonstrated the benefits robotic surgery offers in comparison with traditional surgery, such as less blood loss, less pain and quicker recovery **(5)**. This was further confirmed by the European Association of Urology (EAU) Robotic Urology Section Scientific Working Group in a consensus view document published in 2016 **(E)**. These benefits were also recognised by patients, as corroborated by one who underwent a procedure performed by Prof Dasgupta: "*It's great that something like this can be used to give surgeons more detail and help them to carry out the surgery effectively, so it was very reassuring to know it would be part of my operation* **(B.2)**." A 65-year-old patient who went through the same procedure (also carried out by Prof Dasgupta), was able to get out of bed and go for a walk just one day after his surgery **(B.4)**.

King's changed the programme of care for prostate cancer survivors to include support for the psychological effects of radical surgery (F). The procedure has a high risk of incontinence and impotence, so, GSTT implemented a pre- and post-operative counseling pathway in 2015 to help prepare patients for the psychological and physical effects of surgery ensuring they live a healthier and active life after treatment. Prof Dasgupta supported the pathway by reviewing and analysing patients' feedback forms, which were key from a strategic point of view to improve patient care. He also assisted in the pathway design, streamlined and designed to be patient centered and efficient for both staff (the NHS) and patients.

Multiple seminars were conducted throughout the trial of the pathway with pre- and then post-operative counselling. All patients that attended seminar sessions were satisfied with the experience. Overall, 99% of patients felt more confident in coping with their recovery after they attended the different seminars and 100% of them felt more confident in coping and understanding the discharge process after they attend their discharge seminar.

The Project Manager of the pathway has said: "*If this hadn't been implemented, the situation would be 'status-quo', nothing would have changed for these patients and there would be long waiting lists to see multiple different members of the multidisciplinary team. Prokar's help in implementing*

the pathway was extremely valuable and the work shows how important it is to address patients unmet needs to reduce 'regret', streamline services and overall improve patient experience **(F)**."

King's demonstrated the cost effectiveness of robotic surgery, informing national guidelines in the UK and Canada. Despite improved clinical outcomes, the high cost of purchasing and maintaining the da Vinci system remained a concern for national health services. A systematic review by the King's team demonstrated that shorter hospital stays alone were not enough to offset the cost of expensive disposables. This led to King's researchers partnering with colleagues from the Henry Ford Institute in Detroit and Harvard Medical School to show that in order to be cost-effective, centres needed to perform at least 150 operations per year **(G)**. After proving the cost-effectiveness of robotic surgery, the concept of 'minimum volume' was featured in the NICE prostate cancer guidance in 2019, designating centres performing 150 procedures/year as cost-efficient **(H)**. This resulted in a spike in the use of the da Vinci system in high volume centres to 5-6 days per week **(G)**. In 2020, the Canadian Agency for Drugs and Technologies in Health (CADTH) also utilised the 'minimum volume' concept as a standard recommendation for Canadian health care decision-makers **(I)**.

5. Sources to corroborate the impact

(A) 'New Versius robot surgery system coming to NHS' BBC News Article, 3 September 2018

(B) Sources that corroborate King's establishing Institute of Robotic Surgery at GSTT: B.1 Robotic-assisted surgery at Guy's Hospital website page; **B.2** Annual and Progress Reports for the Vattikuti Foundation on the Institute of Robotic Surgery (2015-18) [patient quote page 16 | 60% of radical prostatectomy operations performed using a robot page 13]; **B.3** Vattikuti Foundation website page; **B.4** Guy's Hospital Website News Article

(C) Testimonial from Chief Executive of The Urology Foundation (TUF)

(D) Sources that corroborate King's developing the first international curriculum for safe training in robotic surgery and its uptake: D.1 Ahmed K, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int. 2015 Jul;116(1):93-101; **D.2** BAUS Robotic Surgery Curriculum Guidelines For Training, 17 August 2015; **D.3** BAUS website showing its workforce numbers

(E) Academic article corroborating benefits of robotic surgery: Collins JW, Patel H, Adding C, Annerstedt M, Dasgupta P, et al. Enhanced Recovery After Robot-assisted Radical Cystectomy: EAU Robotic Urology Section Scientific Working Group Consensus View. Eur Urol. 2016 May 24. pii: S0302-2838(16)30184-1. (http://dx.doi.org/10.1016/j.eururo.2016.05.020)

(F) Testimonial from Project Manager of The Prostate Cancer Survivorship Pathway

(G) Study showing that for robotic surgery to be cost-effective, centres need to perform at least 150 cases per year: Leow JJ, Chang SL, Meyer CP, Wang Y, Hanske J, Sammon JD, Cole AP, Preston MA, Dasgupta P, Menon M, Chung BI, Trinh QD. **Robot-assisted Versus Open Radical Prostatectomy: A Contemporary Analysis of an All-payer Discharge Database**. Eur Urol. 2016 Nov;70(5):837-845. doi: 10.1016/j.eururo.2016.01.044.

(H) NICE Guidance on Prostate Cancer (2019) [points 1.3.15 and 1.3.16]

(I) Canadian Guidelines (CADTH) Robotic Surgical Systems for Use in Gynecologic Oncologyor Urologic Surgery: Clinical Effectiveness, Cost Effectiveness, and Guidelines (2020) [page 11]