Use of Robot Devices in Percutaneous Coronary Interventions & Nanobots which are future Devices in Treatment of Heart Diseases

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Abstract: Robots which are used to do surgery of percutaneous coronary intervention are electromechanical machines that can be used to do surgeries to avoid radiation or ionization repetitive in place of humans. Robots are first introduced in 1990s to clinical medicine. The Robots which are used in Medical field are getting and used widely in surgeries due to advantages like highly precision, speed, reproducibility, great access to the areas which are under operation and endurance. In cardiovascular and coronary medicine, the medical robots are now a day routinely using for minimally invasive cardiac surgeries, with the help of Intuitive Surgical the mitral valve’s repair and for the coronary artery bypass graft surgeries. The medical robots are also being used in clinical us of endovascular surgeries and percutaneous coronary interventionals (PCI). Even though we have enough evidence that supports feasibility and safety of robotic-assisted PCI’s, the robot-assisted coronary interventions are now performed very limited hospitals worldwide. Even though the community of interventional cardiology more aware of today’s potential hazards working in the catheterization laboratories, interventional cardiologists are slow in accepting robotic technology due to learning curves and costs. Percutaneous coronary interventionals (PCI) is widely performed for revascularization of ischemic heart diseases with more than 2 million procedures perform every year worldwide. Technology advancements in interventional equipment’s such as intravascular ultrasound and optical coherence tomography have great optimized outcomes in clinically resulting the procedural success rates more than 97% with very less complication rates. Influenced by the development through robotic approaches in minimally invasive surgery, biomedical engineers are working closely and deeply in developing Robotic-assisted technologies for cardiovascular applications which shows the promise in reducing radiation exposure to the surgeon and also enhanced catheter precision.
And nano robotics article focuses on applications of Nano robots which are used in
diagnosis and treatment of the diseases like heart diseases etc. Nano robots are
controllable machines which are nanometer or molecular in size which are composed
with Nano scale like components. With the help of modern scientific outcomes, it is
possible to attempt and make of nanorobotics deviceand control. These nanorobots
are very helpful in the drug deliveries which is an important aspect in medical
treatment. The recent advancements of these devices are the brain targeted delivery of
drugs, cancer treatment and removal of blood clots. Materials & Methods: The study
was done on patients from the hospital where I am studying from the 2016 March to
2019 March. The numbers of patients taken for the study are 36 with the disease of
Cardiovascular Diseases. Result: The robotic-assisted percutaneous coronary
interventions systems improves surgeons and patients safety by reducing radiation
and ionization exposure and also the quality of procedures and outcomes and
accuracy in stent precision. Telerobotic PCI systems will reduce costs and improve
the access to remote places for coronary care by supporting interventional
cardiologists/radiologists to perform away from site procedures. Considering the
heavy side effects of therapies like radiation the nanorobots in the field of
nanomedicine can be an innovative idea and supportive through nano technology for
patients in diagnosing and treatment of life threatening diseases. Due to this the
future of medicine treatments will shift from medical science to medical engineering
and this will make revolution. Conclusion: In conclusion, the PCI systems will
improve surgeons and patient safety and precision of stents and quality. And the
telerobots will save the life of emergency patients and can be performed from remote
places improve procedural quality and outcomes by offering better accuracy in stent
selection, the potential to reduce costs. Taking the higher side effects of the existing
diagnostics therapies like radiation these nanorobots in the field of nanomedicine will
be innovative optimistic and supportive in field of nano technology for patients in the
diagnosis of life threatening diseases.

Keywords: FFR (fractional flow reserve), CT (computed tomography), PCI
(percutaneous coronary intervention), OCT (optical coherence tomography),
FDA (food and drug administration of US), Virtual Reality (VR), Atomic Force
Microscopy (AFM), Scanning Electron Microscopy (SEM), Red Blood cells (RBC’s).

Introduction

Robots which are used in medical are gaining wide appreciation and use in surgery
because of advantages such as speed, precision, endurance and access to operation.\(^1\)
Medical robots are routinely used in cardiovascular medicine for minimal invasive
cardiovascular surgery such as coronary grafting artery bypass and repair of mitral
valve.\(^2,3\) The trial, safety and feasibility of robotic PCI in a multi-center study has
shown that there is no increase on radiation in 163 patients.\(^4\) Robots have
been evaluated for the clinical use in percutaneous coronary interventions,
endovascular surgery and electrophysiology.\textsuperscript{5,6,7,8,9} Despite many evidence that supports the safety and feasibility of robot-assisted PCI, robotic-assisted coronary intervention surgeries are now performed in limited number of hospital around globe. But in the registry most of lesions treated are simple and not very reflective to real world of clinical practice. The robotic technology in PCI have great scope, “all-comer” cohort in particular, for coronary lesions complex is unknown. In \textit{JACC: Cardiovascular Interventions}, Mahmud et al.\textsuperscript{10} report shows the results of the Complex Robotically Assisted Percutaneous Coronary Intervention –CORA PCI study, which is designed to evaluate the technical success rate, safety, clinical success and feasibility of robotic-assisted PCI (Corindus CorPath 200) in the treatment of coronary artery diseases in a real-world cohort study compared with manual PCI. A total number of 315 patients have been performed 334 PCI procedures in that 108 were robotic PCI, 157 lesions and 226 manual PCI, 336 lesions. The success rate with robotic PCI was 91.7\%, only 11.1\% requiring manual assistance of cases and manual conversion is 7.4\%. Whereas in both groups clinical success, stent utilization and fluoroscopy time is similar between both the groups, but procedure time was longer in the robotic PCI group by about 9 min.

1.1 Robotic PCI System

This robotic-assisted PCI system which enables us to control the coronary guided wires, stents and ballons during PCI from protected control console. Only two robotic PCI systems CorPath 200 and CorPath GRX, Corindus Vascular Robotics are currently available. In these two systems only CorPath 200 is the system that is evaluated to use clinical studies\textsuperscript{10,11,12} which is currently in use. It hastwo functional subunits: one is bedside unit and another is the physician remote workspace. The bedside unit has articulated arm, robotic drive and a singleuse cassette in which devices including wires, balloons, and stents are loaded. The workspace consists of the interventional remote cockpit, control console, x-ray foot pedal, angiographic and hemodynamic monitors which is coveredby a radiation shield and has the control console. During the surgery procedure within the control console the interventional cardiologist can sit comfortably and perform within the shielded environment, protecting himself from the ionizing radiation without wearing the lead apron. The interventional radiologist can choose whether to sterilize and thereby the cardiologist can remain in a sterile gown throughout the procedure, or he can perform the
procedure without a sterile gown. The latter approach facilitates removal of the operator's lead garments during PCI. The control console allows the interventional radiologist to manipulate and control guide wires, balloon and stents using the joysticks and also touch screens mean while fluoroscopy provides the image guidance.\(^\text{13}\) Axial and rotational motion are achieved by a mechanical transmission module. By using the joystick both the stent and balloon can be guided in continuous motion and by using touch screen small and and sensitive steps can be performed. Through motored and roller pair the Axial motion is achieved. If the robotic system has resistance or the motored rollers slide, the motion and sensing rollers report malfunction and the device halts.\(^\text{14}\) Limitations of the CorPath200 system include the lack of haptic mechanical force feedback and inability to manipulate guiding catheters during the complex cases, and wire equipment such as microcatheters and rotational atherectomy devices. The new - generation robot (CorPath GRX) has been recently approved by the US Food and Drug Administration (FDA) and is now in clinical use in the United States and other parts of world. The CorPath GRX system overcomes some of the limitations Specifically, it provides guidecatheter control, it consists of 3 joysticks instead of 2, and it increases the speed of wire rotation for coronary anatomy. Newer generation includes a redesigned bedside unit along with bedside touch screen for ease of use and easy work flow. The CorPath GRX is the only system that can perform both percutaneous coronary interventions and peripheral vascular intervention procedures.

1.1.1 Robotic assisted PCI benefits

Major possible benefit is reduce in radiation exposure by more than 90%-95%\(^\text{15,16}\). Most important pointis simple adoption of low-frame pulsatile fluoroscopy which is coupled with storing fluoroscopy sequences instead of cine image acquisition which dramatically reduce radiation exposure to both patient and operator\(^\text{15}\). Other maneuvers to reduce radiation dose include the avoidance of high magnification as well as limiting steep angulations. More over the operator apron technology has been evolved with new 2-piece design, inclusion of head and hand protection, lighter materials and better belt support\(^\text{15,17}\). Other approaches like Zero-Gravity (Biotronik) virtually will eliminate any radiation or other issues like orthopedic problems for the operator\(^\text{18}\). Cumulative doses for interventional cardiologists are in the range of 50 to 200 mSv, after30 years of working and some professionals with lifetime attribute to
excess cancer risk 1 in 100 in the order of magnitude. This Robot-assisted PCI will reduce radiation exposure by 97%. According to Roguin and colleagues self-collected and reported data on 31 brain tumors among physicians who are exposed to ionizing radiation, the majority of them are interventional cardiologists. They have found out that the brain tumors were left sided in 85% of the cases. Cancer on the Left side brain will have effects of brain tumors, breast cancer.

1.1.1.2 Injuries:

In recent survey of society for cardiovascular interventional radiologists members 153 out of 314(50%) responded to orthopedic problem. As interventional procedures are becoming more complex, we can expect that interventional cardiologists are spending more time standing wearing leaded apron personal protection equipment which exerts continuous force on the musculoskeletal system. Most common orthopedic injuries were cervical and lumbar injuries, and injuries are strongly correlated with case load and performer age. Sousing robotic assisted PCI system which has potential to minimize orthopedic injuries.

1.1.1.3 Accuracy of Lesion coverage

While using robotic assisted PCI, the interventional cardiologists can use a special measurement feature by advancing the markers of balloon to the distal and proximal edges of the lesion. The distal edge can be marked as “0” on the touch screen display. Next step is by withdrawing the balloon marker to the proximal edge of the lesion, measurement of the lesion length is provided by marker distance travelled. The robot-assisted PCI system has improved accuracy compared with the visual estimates interventionalists use today. Targeting vessel revascularization is concern in contemporary interventional cardiologists practice. But this information has to be confirmed with upcoming clinical data, by improving accuracy of lesion and length assessment, this robotic assisted PCI has the potential to reduce the risk in stent restenosis and improve patient outcome. The percussion of precise robotic lesion measurement on stent length selection was studied on 60 consecutive patients by Campbell and his colleagues. The study displays that, compared with robotic measurement and visual estimated lesions (35%) resulted in accurate perfect stent selection, whereas 33% of stents are long (25±13 vs 18±11, P=0.002) and 32% are short (20±9 vs 23±11, P<0.001).
1.2 Tele robotics of Interventional Radiologists:

The first-in-human (FIH) Telerobotic Intervention Study was conducted on Dec. 4 and 5, 2018, in India. This study shows the world’s first percutaneous coronary intervention (PCI) was successfully conducted from a remote location outside the catherization lab.

The Five patients were located at the Apex Heart Institute in Ahmedabad, Gujarat, who underwent an PCI procedure from a distance of roughly 32 km away. Each of PCI procedure was remotely performed from inside the Swaminarayan Akshardham temple located in Gandhinagar by Dr. Tejas Patel, M.D., chairman and chief interventional cardiologist at the Apex Heart Institute. Dr. Sanjay Shah, M.D., partner of Dr. Tejas was in the catherization room along with the patient at the Apex Heart Institute. This success of this study shows the way for large-scale, long-distance of telerobotic platforms across worldwide, according to the Corindus. The use of Robotic PCI first-in-human case represent a landmark event for interventional medicine.

1.3 Single operator at Multiple sites:

Physicians are important in healthcare costs, and this is true in the field of interventional cardiology. At every primary PCI in remote areas an experienced operator is available 24*7 and 7 days a week. As robots are becoming cheaper and more capable of performing these robotic systems can help in reducing the costs of catheterization labs in off-site areas. By allowing only 1 experienced interventional radiologist to support and control multiple remote sites with the help of tele medicine.

2.1 NANO ROBOTS:

The name “nano” originated from the Greek wording “dwarf”. In 1959 by Richard Feynman the concept of nanotechnology was explained, who is Nobel Prize winner in a lecture named, “There’s plenty of room at the bottom”. He concluded the lecture by saying “this is a development which I think cannot be avoided”. The term nanotechnology was framed by a student in 1974 at Tokyo science university. Nanotechnology is a subject which involved in the study, design, making, synthesis, manipulating and application of materials, devices, systems in the nanometer scale. There are 1 billion nanometers in one meter. Nanotechnology can best be explained as a narrative of activities at the level of atoms and molecules that use applications in the real world. A nanometer is a measures in size billionth of a meter, i.e, about 1/80,000 width of a human hair, or 10 times the width of a hydrogen atom. Nanotechnology
has become a part of applied science whose subject is to control the molecular scale and matter on atomic scale. It has become important role in health care. The nanotechnology application in the field of health care has come under great thinking in recent times. Now a day’s different kinds of treatments are available which consumes time taking and expensive. By using nanotechnology, we can make it faster and much less expensive treatments can be developed.

2.1.1 Nanorobots:

Nano robots are the Nano devices that are used for protecting or treatment against pathogens in humans. It is a tiny device which is designed to do a particular work or sometimes work with precision at nanoscale measures of 1 – 100 nm. According to nanorobotics theory, “Nano robots are microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks”.

The main element used in making Nano robots is carbon material because of its inert and has good strength. Nano robots have exterior passive diamond coating specially to avoid attack by the host immune system. They are not visible to our naked eye. Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) are being used as base to visualise and haptic interface will enable us to sense the molecular structures of Nanodevices. Virtual Reality (VR) technique is currently under exploration in Nano-science and bio-technology research in a way to enhance the operator’s opinion by advancing more or less in a state of full immersion or telepresence. Nanorobotics is a field which comprises of collaborative efforts made by physicists, chemists, biologists, computer scientists, engineers and other specialists to work towards with common objective. Currently this nanotechnology is still unfold, but several steady moves have been taken by great researchers from all over the world to this challenging and exciting field.

2.1.1.2 Nano Technology for Diagnosis and Imaging:

They consist of microchips that are coated with human molecules. The chip is predicted to send an electrical signal/image when the molecules detects the disease. Advantages are these it can be produce and low price and it can be easy to manipulate.

2.1.1.2.1 Respirocyte:
It’s an nanobot which carries oxygen which is an artificial red blood cell. The power is obtained from endogenous serum glucose. This cell is able more oxygen 236 times to the tissues per unit volume more than RBCs (Red blood cells)\textsuperscript{36}

2.1.1.2.2 Advantages of nanorobots:

- Nanorobot can be used drug delivery systems with increased bioavailability;
- Used for Targeted therapy.
- It can Reach remote areas in human body which can’t be operated at the surgeon’s operating table.
  - It’s an Non-invasive technique;
  - By using Computer controlled operations with the help of nobs we can fine tune the amount, frequency, time of release.
  - Better preciseness.
  - Drug inactive in areas where therapy not needed thus minimizing side effects\textsuperscript{36}.
  - Small size- The upper limit of the size of nanorobot is 3 microns so that it can easily flow in the body without blocking the capillary flow.
  - Cost effective (if mass produced).
  - Less post treatment care\textsuperscript{37}.

2.1.1.2.3 Knives, chisels and probes

These are used in removing plaque and clogs. These help Nanorobot to snatch and break down the material. Also we might require a device to crush clots into very small pieces. If a partial of clot breaks down and is free it enters the bloodstream, it may cause more problems in circulatory system.

2.1.1.2.4 Lasers:

These are used to burn the harmful materials like blood clots and plaques i.e. these lasers vaporize tissues. But this laser does not harm to surrounding tissues.

2.1.1.3 Power supply for nanorobots:

The major requirement for the nanorobot is, of course, power. The nanorobots require power to allow it to perform its operations. There are two possible ways.

The first is to obtain the power from a source within the body, either it should have own power supply, or need to get power from the bloodstream.

The second possibility way is to have power supply from a external source into the body.
2.1.1.7 Nanorobot in Heart-attack prevention:

Nanorobots can be used to prevent heart-attacks. Nanorobots can be made for removing fat deposits. These nanorobots remove the yellow fat deposits inside of blood vessels. This will allow for blood flow, improve the flexibility of the walls of the arteries\textsuperscript{38}.

From this hypothesis, such technology will help for delivery of drugs like lipid lowering substances such as lovastatin, simvastatin etc. These drug molecules will enter with nanorobots and give delivery at the site of action\textsuperscript{29,34}.

With the use of Nano Robots High impact can be expected if diseases are diagnosed earlier, which impose the high burden on the aging population: cardiovascular diseases\textsuperscript{39,40}. Materials and Methods

Robotic-Assisted Cockpit

A. The robotic system arms which allows for precise control with millimeter movements of wires and devices. (B) Cockpit design which permits easy visualization on multiple monitors of multimodality imaging. (C) Example of Heart Flow FFR-CT PCI planner with visualization of coronary arteries to determine precise lesion length (left-hand panel with dotted line) and then restoration of normal coronary flow and FFR following stent
deployment (right side panel). (D) OCT and angiography which enables precise positioning of the stent by projecting landing zones into the angiographic image.

New Generation CorPath GRX

Dr. Tejas Patel who performed first human telerobotic coronary intervention
Nanobot fictitious Pharmacyte:

It is a medical Nano robot having a size of 1-2 μm able to carrying up 1 μm of drug in the tanks.

Nanorobots in blood vessel for Diagnosis and Imaging:

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Nanorobots removing fat deposit:

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Result

The robotic-assisted percutaneous coronary interventions systems improves surgeons and patients safety by reducing radiation and ionization exposure and also the quality of procedures and outcomes and accuracy in stent precision. Telerobotic PCI systems will reduce costs and improved the access to remote places for coronary care by supporting interventional cardiologists/radiologists to perform away from site procedures. Considering the heavy side effects of therapies like radiation the nanorobots in the field of nanomedicine can be an innovative idea and supportive in nano technology for patients in diagnosing and treatment of life threatening diseases. Due to this future of medicine treatments will changeover from medical science to medical engineering and this will make revolution.
Conclusion
In conclusion, the PCI systems will improve surgeons and patient safety and precision of stents and quality. And the telerobots will save the life of emergency patients and can be performed from remote places improve procedural quality and outcomes by offering better accuracy and the potential to reduce costs. Taking the higher side effects of the existing diagnostics therapies like radiation these nanorobots in the field of nanomedicine will be innovative optimistic and supportive in field of nanotechnology for patients in the diagnosis of life threatening diseases.

Limitation
As I planned before starting my thesis to do very briefly and to elaborate more in detail regarding the use of robotic devices for performing Percutaneous Coronary Interventions and Nano Robots. But due to lack of time and also less availability of material which is required for my thesis so I couldn’t discuss in detail. Pictures used in the article are sourced from google source.

References


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