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# The Use of Electric Motors in Human Body: A Review

Seminar paper

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# Contents

**Abstract**

The medical field is in constant search of new and better solutions for old problems. That is where electric motors have helped a lot. Electric motors and other motor-like electromagnetic actuators are being increasingly embedded inside the human body to restore the body's functions. with their precise and controllable movement in the devices that interact with, or are implanted in the human body. This review explores the integration of electric motors in prosthetics, orthotics, assistive exoskeletons, and certain implants. We examine current developed technologies, biological challenges, ethical considerations, and future trends.

**Keywords:** Electric motors, medicine, implantable devices

# 1 Introduction

The use of electric motors in human medical applications has in the past few decades increased significantly. Advances in microelectronics, material science and power systems have led to highly capable electromechanical devices that can interact with the human body for varius purposes. These applications include motorized prosthetics, exoskeletons, surgical devices and even implantable systems such as ventricular assist devicas (VADs). The integration of electrical motors into biomedical devices can enchance patient mobility and improve their quality of life.

# 2 The basics of electric motors

An electric motor is a machine that converts electrical energy into mechanical energy with its rotation. We know many different electric motors; one of the main differences is their power source (DC or AC). Electric motors are used practiclly everwhere and are used for small and big applications. We use them in toys, everyday electronics, cars and also in industry, in hydraulics and robotics.
In this article we will pay special attention to brushless DC motors, which are synchronus motors. The brushless DC electric motor is made of the rotor and the stator. The rotor spins with magnets and the stator has coils of wire. Electricity is sent into the coils of the stator in a special sequence, this creates a magnetic field that pulls and pushes the rotor's magnets. As the rotor moves, sensors or other smart electronics detect its position. The electronics then switch the current in the coils at the right time. This cycle repeats very fast, keeping the rotor spinning smoothly as is shown on the pictures (1).


(a) First position (b) Second position

Figure 1: Rotation of brushless DC electric motor (1)

# 3 Applications of electric motors in the human body

## 3.1 Motorized Prosthetics

One of the most impactful applications is in prosthetic limbs. Modern motorized prosthetics use compact electric motors to replicate natural movements such as walking, grasping, and rotating joints. Myoelectric signals (tiny electrical signals generated by muscle) from the user's muscles are often used to control these motors, creating intuitive and responsive control systems. Examples include the bebionic and DEKA "Luke" arm shown on picture (2), which offer multi-articulating fingers and wrists powered by small, high-torque electric motors. It uses more than 8 electric motors, the smallest ones being in the fingers. The big number of electric motors allows user relatively precise movement in fingers, wrist, elbow and shoulder. Another use of another motorized prosthetic hand is shown on picture (3) where we can see the use and positioning of electric motors.

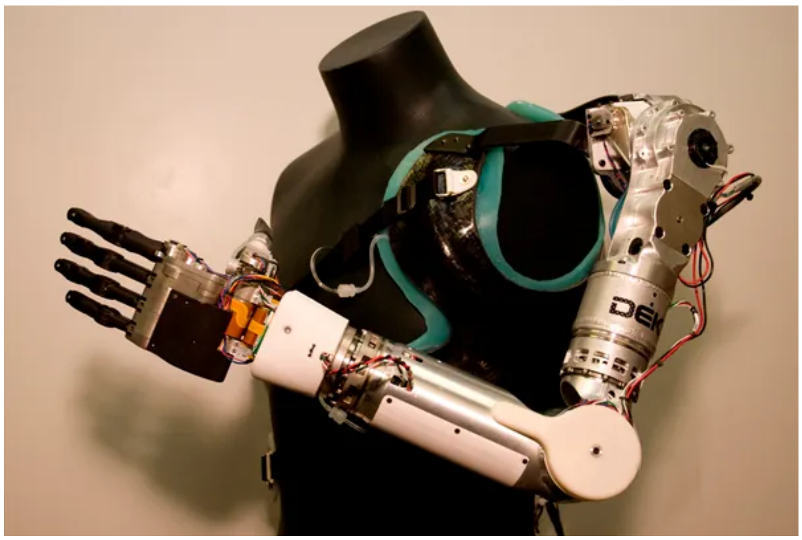


Figure 2: DEKA's Luke arm (2)

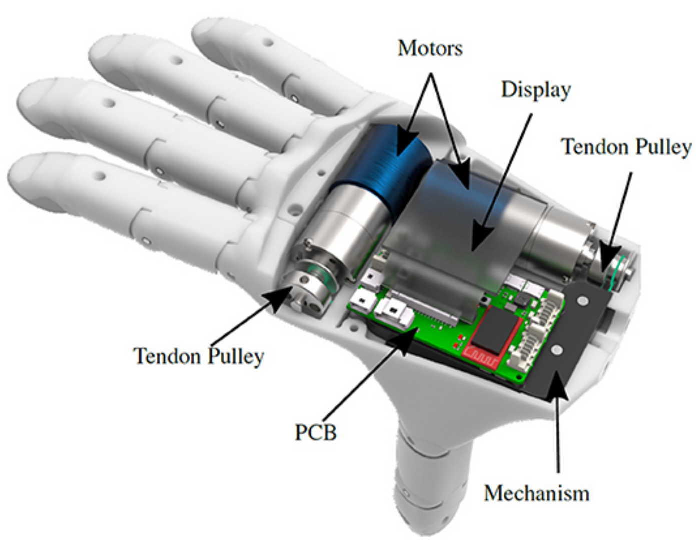


Figure 3: Prosthetic hand example (3)

## 3.2 Orthotics and Exoskeletons

Powered orthoses and wearable exoskeletons assist individuals with impaired mobility. Electric motors in these devices help compensate for muscle weakness, spinal injuries, or degenerative diseases. For instance, devices like ReWalk and Ekso Bionics use motorized joints to support hip and knee motion, enabling paraplegic users to stand and walk. These devices rely on feedback loops involving sensors, electric motors, and control algorithms to synchronize movement with the user's intention. They are not used only by those with impaired mobility but also by companies where the workers have to work with, and transfer heavy pieces or equipment. Exoskeletons help them with the heavy load making the job easier for the worker. An example of a motorized exoskeleton used for workers is shown on picture (4).

Figure 4: An example of motorized exoskeleton (4)

### 3.3 Implantable Devices

Electric motors are also used in internal implants. One prominent example is the ventricular assist device (VAD), which helps patients with heart failure by mechanically pumping blood. The continuous-flow VAD uses brushless DC motors to generate a consistent blood flow with minimal noise and wear. Emerging research also investigates motor-based systems for controlled drug delivery and active stent adjustments within the vascular system. The VAD is shown on picture (5).

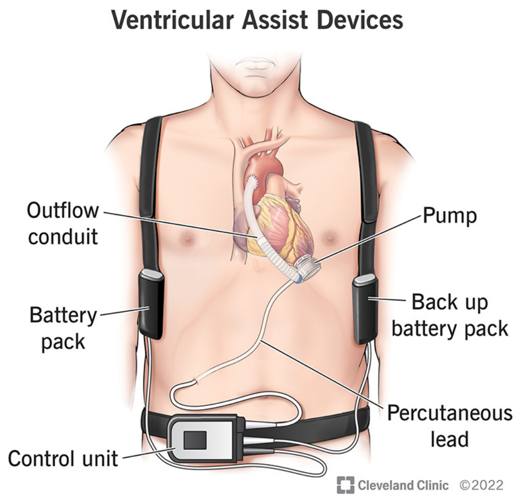


Figure 5: VAD (5)

Another prominent example is the Carmat Aeson, a fully implantable artificial heart approved in the European Union as a bridge-to-transplant therapy. It utilizes motor-driven hydraulic pumps: internal motors circulate hydraulic fluid that flexes biocompatible membranes to replicate natural myocardial action. Sensors detect hemodynamic changes, enabling the motor system to adjust output in real time. The whole device is shown on pitcure (6) and the inside of the heart itself is shown on picture (7).

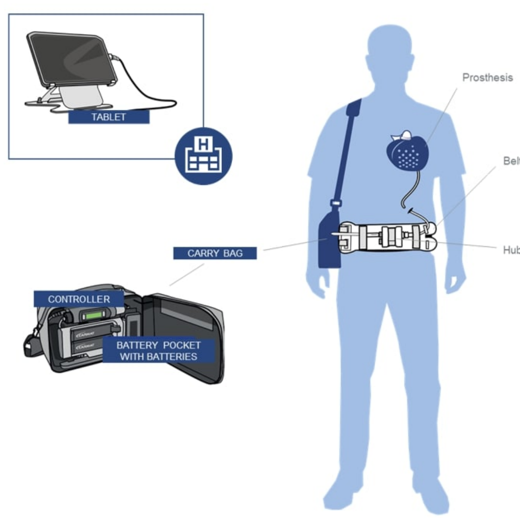


Figure 6: The Carmat Aeson heart (6)

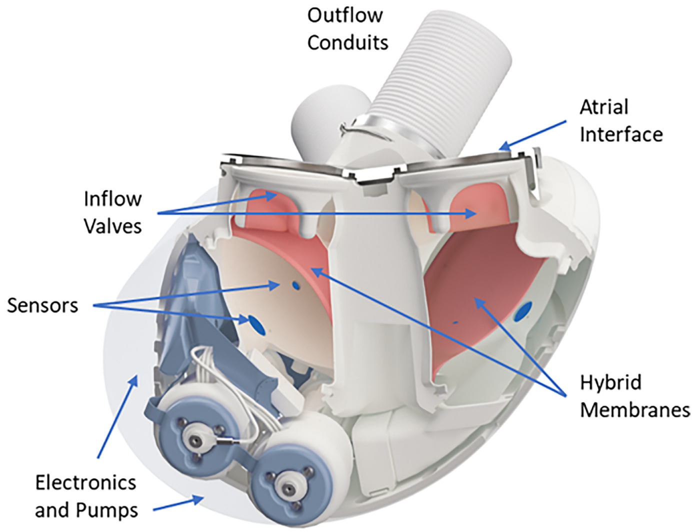


Figure 7: The inside of Carmat Aeson heart (7)

## 4 Challenges and Considerations

### 4.1 Adequacy of electric motors

As we know there are many kinds of electric motors, with different characteristics. Not every electric motor is adequate to be used for the human body or especially inside of the human body. They must be precise, with clear and smooth movements, and must not afford failure. In this field most appropriate electric motors are Brushless DC motors, Stepper motors and piezoelectric motors. Brushless DC motors are most commonly used because they do not have tear and wear of the brushes therefore have less chance of failing or something going wrong. They also offer exceptional longevity, which is essential for the devices that must function inside the body for years. It also delivers a high power to weight ratio, which means it allows strong performances in small dimensions, because as we know the body has very limited spacing and we must not hinder other organs with our device. The brushless DC electric motor runs quietly, without sparks and without overheating, it also allows great and precise speed and torque control including smooth start/stops. A crucial point is also their ability to withstand sterilization processes. They also have low electromagnetic interference which is VERY IMPORTANT for a medical device. The engineer's goal when designing such devices must always be a device that will benefit the patient. A device that will require minimal number of surgeries or interventions off which the main couse would be the device.

### 4.2 Biocompatibility and Safety

Electric motors must meet stringent biocompatibility requirements, as the smallest mistakes can put the patients life in danger. Materials must be non-toxic, non-corrosive, and must not elicit immune responses. Additionally, motorized devices must be fail-safe, as a malfunction could result in injury or death. If the materials are not suitable they can couse serious allergic reactions, or reactions with other organs and tissue which can cause serious additional health problems that weren't there at the beginning of treatment. Special attention is given to heat generation, power surges, and electromagnetic interference. That is why the devices must pass strict testings. The most commonly used metals are Titanium and Titanium alloys, because of their strenght, lightness, they are also corrosion-ressistant and can bond to the bone (useful in full titanium frames). Other appropriate metals are also stainless steel, cobalt-chromium alloys and tantalum. We can see an example of titanium electromotor of different sizes on picture (8), from company Mirmex Motor which specializes in electric motors for the use in medical devices .


Figure 8: Electrical motors for implantable devices (8)

### 4.3 Power and Miniaturization

Efficient energy management is a primary concern. Batteries must be compact, long-lasting, and capable of providing consistent power without frequent recharging. This becomes particularly critical in implantable devices where battery replacement requires invasive procedures. Efforts in wireless power transfer and energy harvesting are under development to address these limitations. Currently most commonly used power sources for medical devices in or on human body are:
-**Lithium batteries**: used on the outside of the body, so they can be changed (and to not risk lithium spillage). They are favorable because of their high energy density, long service life and stable voltage output. Mostly used in cardiac pacemakers and neurostimulators.
-**Wireless power transfer**: That includes inductive power transfer where inductive coupling employs magnetic fields between coils to deliver power from the coil on the outside of the human body to the one inside it. It is usually used in VADs. We also know of ultrasonic energy transfer where an implanted piezoelectric reciever captures ultrasound which allows charging.
-**Other**: We also know ways off harvesting power from the body itself, for example with piezoelectric components, thermoelectric generators and chemical energy harvesting. But their development is still in the works and is not as reliable as other sources and often times does not provide enough energy.

### 4.4 Control Systems

The interface between human neural or muscular signals and electric motor control is a key area of research. Several approaches to control exist:
**Myoelectric control**: Surface electrodes detect electrical activity from residual muscles. These signals can be used in a simple on/off fashion, proportionally (stronger contraction = stronger motor output), or processed through pattern recognition to distinguish multiple intended movements. This is the most common form of control in motorized prosthetics today.
**Targeted Muscle Reinnervation (TMR)**: Nerve endings that once controlled the missing limb are surgically rerouted to new muscle sites. When these muscles contract, they generate strong, easily detectable myoelectric signals that can control multiple motor functions more intuitively.
**Peripheral nerve interfaces**: Electrodes placed closer to or directly on nerves allow more precise signal acquisition, enabling finer control of individual joints and digits in prosthetic hands.
**Implantable medical devices**: In devices like ventricular assist devices (VADs), control systems operate more autonomously. Sensors continuously monitor physiological parameters (e.g., blood flow, pressure), and the motor's output is automatically adjusted in real time to match the patient's needs. Similar closed-loop approaches are used in cochlear implants and deep brain stimulators, where feedback from biological signals refines stimulation patterns.

Reliable signal acquisition and interpretation are crucial for responsive performance. Machine learning algorithms are increasingly employed to refine motor control systems based on user-specific movement patterns and feedback.

## 5 Ethical and Social Implications

While electric motor-based devices provide significant benefits, they also raise ethical questions. The potential for human enhancement (beyond normal function) has led to debate in both academic and public environments. The issues related to accessibility, cost, and long-term effects must also be considered to ensure equitable distribution and responsible innovation. Of course, patient life and well-being must be a priority, but at the same time, limitations to what kind of power a human can access must exist.

## 6 Future Directions

The next generation of motorized biomedical devices will likely feature improvements in miniaturization, power efficiency, and neural integration. Brain-machine interfaces (BMIs) will allow direct control of electric motors via thought, removing the need for intermediary muscle signals. Research into soft robotics and biohybrid systems promises devices that more closely replicate natural muscle function. Furthermore, AI-driven personalization of motor control could make devices more adaptive to individual physiology and behavior.

## 7 Conclusion

Electric motors have emerged as vital components in a variety of biomedical devices that interact with or reside within the human body. From restoring lost functions in amputees to supporting vital organ activity, their contribution is undeniable. While technical and ethical challenges remain, the field continues to advance, offering increasingly sophisticated solutions to medical needs. Continued interdisciplinary collaboration between engineers, physicians, and ethicists will be essential to fulfill the full potential of electric motors in medicine. The current already existing devices in the field are essential for the future advances. The motorized devices that are designed for the human body offer patients a hope for new and easier life, and help them in everyday achievements.

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