

An Automatic Intravenous Drug Injection System

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Abstract: The report describes the development of an automatic intravenous drug injection system to a patient in the absence of medical personnel near him. A list of pathological conditions has been determined, upon the occurrence of which the immediate administration of drugs is required. Instrumental research methods are proposed, the use of which makes it possible to carry out intravenous injection in an automatic mode. The results of the implementation of modules of the injection system using the component base of mechatronics and electronics are discussed. A generalized block diagram of the developed system is presented.

1 INTRODUCTION

There are several diseases in which, at critical moments, there is an urgent need to promptly obtain a therapeutic effect in the shortest possible period of time. Such diseases include, for example, hypertensive crisis, hypoglycemic coma, life-threatening cardiac arrhythmias, acute allergic conditions and pain syndromes. In such situations, it is important to immediately provide a person with first aid and with the necessary medicines. As a rule, intravenous injection is the most effective and efficient method of drug delivery (Wheeler et al, 2020; Mohapatra et al, 2018).

Angioedema (or Quincke's edema) is one of the most common complications in various forms of allergic reactions, including those caused by food allergens, plant pollen, animal hair, or even such ordinary physical factors as cold and bright sunlight (Ilkova et al, 2021; Plavunov et al, 2020). Due to the fact that with Quincke's edema, the situation can change within seconds and the slightest delay is life-threatening, there is a need for a quick response. This can be especially important during a flight or when providing first aid in kindergartens and schools (Zudaire et al, 2021; Sanchez-Borges et al, 2017).

Allergic attacks are easily stopped with proper treatment and prevention, but there are cases, especially if the appropriate drug is not administered in a timely manner, in which the outcome can be fatal. Recently, more and more often there are patients with the so-called polyvalent allergy, that is, those in whom acute reactions are caused by several allergens at once. The danger of this form of the disease is that such reactions are unpredictable: it can be difficult for a person to take adequate measures. Due to the large number of allergens that can provoke an attack, it is extremely difficult for patients with polyvalent allergies to completely protect themselves from interacting with them. Therefore, it is important to provide people suffering from this disease with the additional elements of self-help in case they unexpectedly face appearance of the allergy attack exacerbation symptoms (Inagaki, 2021). An emergency intravenous injection of antihistamines or hormones given before an ambulance arrives or, for example, during a flight before an airplane lands at an airport, could help avoid life-threatening complications and jugulate the development of Quincke's edema or anaphylactic shock (Plavunov et al, 2020).

A similar principle of reaction is also suitable for patients with bronchial asthma, who observe a sharp

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exacerbation of the disease against the background of interaction with an allergen. In such situations, intravenous administration of drugs can significantly increase their bioavailability, compared, for example, with more conventional inhalations (Dahat, 2021).

Injections into a muscle or vein are also the primary way to lower blood pressure in persistent hypertension that turns into a severe hypertensive crisis. More recently, only elderly people suffered from hypertension, but now this ailment is increasingly diagnosed in younger patients. In addition, pregnant women are susceptible to arterial hypertension after the 20th week. Until now, intravenous injections of combination drugs based on magnesium sulfate remain the most effective method of treating high blood pressure in acute cases (Wang et al, 2019).

Treatment of hypertensive crises in elderly patients is often complicated by the problems of emergency medical care at home. Frequently, first aid for the elderly requires special medications, some of which are administered as intravenous injection. In some cases, it is important to supply the injection immediately. However, most people looking after their aging relatives do not have the appropriate skills. The situation becomes even more critical when an elderly patient who suffers from high blood pressure lives alone. A system that excludes waiting time for medical attention and correct delivery of the injection could become a possible solution.

In addition, there is a need to avoid complications associated with an injection technique violation. Among them the most common and dangerous are sepsis, viral hepatitis and HIV infection, due to non-compliance with the rules of asepsis and antiseptics, and various violations caused by unsuccessful venipuncture. In addition, there is a certain need to find a good alternative to intramuscular injections, which are often prescribed in the treatment of spinal injuries, osteo-articular diseases and disorders of the nervous system.

The danger of such injections lies in the fact that in most cases, patients with the spinal injuries or osteo-articular that do not require hospitalization diseases are treating themselves according to the doctor's guidance at home. This can lead to the fact that people who do not have special medical training unintentionally injure themselves with careless administration of drugs. For example, a simple injection administered in the gluteal muscle, often lead to a serious complication such as sciatic nerve injury (Jung Kim & Hyun Park, 2014). According to official World Health Organization statistics, getting such injuries is very common, even though not all cases of sciatic nerve injuries are registered in

hospitals. For effective prevention of such injuries, it is advisable to completely avoid intramuscular injections, and when this is not possible, consider replacing intramuscular administration of the drug with intravenous system.

In view of all these considerations, the development of a portable device that automates the process of intravenous drugs administration is essential for ensuring safe first aid in emergency situations when the access of medical personnel to the patient is difficult or impossible. The automatic intravenous drug injection system, furthermore, is able to protect patients who need regular injections carried out outside the control of the qualified medical personnel.

The aim of the study is to develop a portable system for automatic intravenous drug injection to a patient in the absence of medical personnel next to him.

2 RESEARCH TASKS

To achieve this goal, the following tasks were solved:

1. Justification and selection of a set of instrumental studies necessary for mapping blood vessels in injection and determining the depth of puncture in non-clinical conditions using portable technical means.
2. Justification and development of methods for mapping blood vessels in the injection area and determining the puncture depth suitable for use in a portable injection system.
3. Justification and development of a portable system structure for the automatic intravenous drug injection.

3 RESEARCH PROBLEMS SOLUTIONS

3.1 Justification and Selection of a Set of Instrumental Studies Necessary for Mapping Blood Vessels in Injection and Determining the Depth of Puncture in Non-clinical Conditions using Portable Technical Means

For qualitative determination of the injection site and puncture to the required depth, it is necessary to know the spatial location of blood vessels in the anatomical

area of the injection, as well as the depth of each of them.

To determine the spatial location of blood vessels at the intended injection site, it is advisable to use a thermographic method of investigation, since it is non-invasive and simple in the study of subcutaneous structures of the body. Thermography is based on the method of obtaining a blood vessels subcutaneous pattern using near-range infrared (IR) radiation. In this method, the image of blood vessels positions in the intended injection site, which does not depend on the ambient temperature and the temperature of the person himself, is formed.

There are two ways to obtain an image of blood vessels using IR radiation. The first is based on the transmission of IR radiation through the study area, the second is based on the reflection of IR radiation. For a portable device, the use of the second method is preferable since its use involves fewer design difficulties and allows making the system more compact.

To determine the depth of the blood vessels under the skin in the injection area, it is advisable to use ultrasound examination methods. When using ultrasound scanning, it becomes possible, firstly, to distinguish the arteries and veins in the injection area, and secondly, to calculate the distance to the anterior wall of the required blood vessel.

There are various methods for calculating the distance to the vessel wall, which are used, for example, in carrying out the vein catheterization under ultrasound control. Dopplerography, methods of which allow to determine the type of blood vessel and the distance to its walls by analyzing the direction and speed of blood flow in the target vessel, is also often used for puncturing blood vessels. Existing studies prove the effectiveness of the ultrasound methods during manipulations with blood vessels, for example, during the implementation of vein catheterization. It may be concluded therefore that the ultrasound scans can also be used in the development of an automatic injection system.

3.2 Justification and Development of Methods for Mapping Blood Vessels in the Injection Area and Determining the Puncture Depth Suitable for Use in a Portable Injection System

It would be useful to divide the implementation of the injection procedure using a portable automatic system into three stages:

1. Generating image of subcutaneous blood vessels at the intended injection site based on thermography data.
2. Distance determination to the anterior wall of the vein selected for injection using ultrasound methods.
3. Injection into a vein using an automatic injection system.

During the first stage, the intended injection site is irradiated with near-range infrared radiation. Then the thermogram is recorded in reflected IR light, after which the obtained data is preprocessed, noise is eliminated, and then, based on the analysis of the obtained 2D image, a spatial map of blood vessels at the intended injection site is formed.

During the second stage, a linear ultrasound scan of the intended injection area is performed, based on the obtained 2D image – visualization of the injection area, a vein that has the most convenient location for injection is selected, then the distance to its anterior wall is calculated in accordance with a specific technique, considering the specified trajectory of needle insertion.

During the third stage, the drug is automatically injected into the vein using a syringe with a thin needle. The movement of the needle is carried out according to a programmed trajectory.

The proposed methods are simple and effective to achieve the purpose of the study. At the same time, existing technologies, when used in conjunction with the selected methods, allow to make the system of automatic intravenous drug injection compact.

3.3 Justification and Development of a Portable System Structure for the Automatic Intravenous Drug Injection

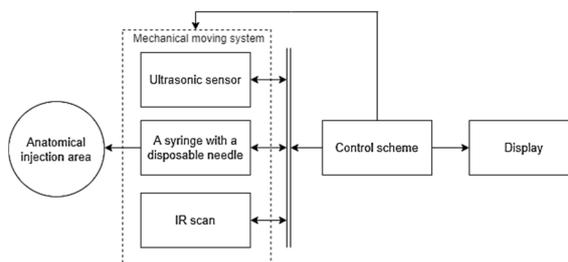


Figure 1: Generalized structure of the automatic drug injection system.

The system for automatic intravenous drug injection includes a mechanical moving head with an IR scanner detector placed on it, whose signals are sent

to the machine vision subsystem to form a map of blood vessels at the intended injection site, an ultrasound scanner sensor to determine the depth of the vessels, as well as an injection system in the form of a syringe with a thin disposable needle. The control module receives data from the ultrasound sensor and the IR scanner, processes and analyses the data obtained to map the location of vessels in the intended injection area, selects the injection vessel and calculates the distance to its anterior wall to determine the depth of the puncture in accordance with a predetermined needle insertion technique. The results of processing the map of the vessels location in the injection area, as well as visualization of the injection area in the ultrasound range appears on the display of the injection system. The stages of the injection procedure are also managed by using the control module, which drives the mechanical system and thus the stages of the injection procedure are changed. The control module includes elements that manage the movement of each of the scanning parts of the injection system, as well as elements for starting and stopping the procedure and a system for displaying the processing results.

The report discusses the results of the system modules implementation using the component base of mechatronics and electronics.

4 CONCLUSIONS

There are several diseases where the need to obtain a therapeutic effect as soon as possible after the onset of an attack becomes critically important for the subsequent survival of the patient. One of the most effective ways to deliver drugs to the body is intravenous injection. The result of the study is the structure of the injection system, which allows through the use of non-invasive scanning systems to accurately localize the injection site and inject the drug intravenously in automatic mode, without the need for the presence of medical personnel. The results obtained allow us to summarize the experience of developing non-invasive scanning systems for localization of blood vessels, generalize the ways of practical implementation of system elements using the component base of mechatronics, improving the accuracy of localization of the drugs injection point, sum up a comparative analysis of the effectiveness of automatic and medical injection.

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