

Design and Development Prototype of Indigenous Robotic Radio Pharmaceutical Dispenser

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Abstract - Working in the nuclear medicine department leads to a possibility of long term low level radiations exposure. Imaging technologies like positron emission tomography (PET) and single photon computer tomography (SPECT) requires radiopharmaceuticals to be administered into the patients. There is radiation exposure to the staff especially when they dispense the required radioactive medicine doses with their hands into the syringes from the source vial. Also, during the process there is a possibility of spillage of the radioactive pharmaceuticals which could lead to radioactive contamination. This project aims at automating the steps involved in dispensing the unit doses into the respective syringes from the source vial and placing it in a lead shielded container. This will be achieved by developing a robotic application to carry out the activities. This will reduce the time for which the nuclear medicine staffs is exposed to the radioactive syringe. The only time when he will be exposed will be when it is injected into the patients.

Keywords: nuclear medicine, dispensing, radioactive exposure, radioactive contamination, automation, syringe

I. INTRODUCTION

The importance of automatic dispenser is well established in various industries and in medical field to reduce direct human contact with the material to be handled. Along with increasing the accuracy and reducing the time for dispensing activities it also reduces the human interaction while handling hazardous materials like reactive chemicals, radioactive materials and fluids at high temperatures. The direct handling of radioactive materials mainly radiopharmaceuticals has been restricted by the International Commission on Radiological Protection (ICRP). It has set dose limits of 20mSv/year for whole body and 500mSv/year for fingers. It also emphasizes that the radiation exposure of patients and workers should be kept as low as reasonably achievable (ALARA principle) [1] [2]. As per their guidelines time, distance, shield protocol has to be followed while handling radioactive materials. Time of exposure can be reduced and distance from the radioactive material can be increased by remote handling of radiopharmaceuticals which in turn reduces the exposure to the operator.

Several studies have been carried out to study the radiation exposure of the nuclear medicine staff handling

radiopharmaceuticals [7-9][10][12-15]. Different techniques have been adopted in order to reduce the radiation exposure to the people while handling radiopharmaceuticals. One of the important techniques reported is proper planning and streamlining the workflow. In this, a proper flow of patients is ensured by maintaining time gap between two patients undergoing PET/CT scan. Post injection and post scan waiting areas in isolation have been maintained for the patients and after the scan the patients are instructed to leave the department. This leads to a reduction in exposure of the staff through the patients [3][7][11]. Studies have shown that if the activities i.e. kit preparation, dispensing, and injection are performed without proper radiation protection measures, finger dose might reach up to 420 mSv, which is close to the 500 mSv annual finger dose limit [3]. The operation of transferring the radioactivity from vial to the syringe is carried out behind the lead shield. The shields used in this case are lead bricks and lead glass, but the hands remain unprotected. Positron emitting radionuclide have high effective dose rate constant. Hence, hand dose to the individuals drawing up and administering PET radiopharmaceuticals can be substantial if larger amount of radioactivity is to be dispensed [3] [11]. Although use of a syringe shield is a practical solution to reduce radiation dose to fingers during manual injection to an extent, other efficient systems such as automatic (or semiautomatic) dispensing/injection systems have been recommended to limit the finger dose. Another study has emphasized on the use of personal protective equipment like lead apron but it is very heavy particularly while handling high energy gamma radiation like PET radiopharmaceuticals.

Also there is more chance of radioactive spillage and associated contamination while manually handling radiopharmaceuticals. In such cases proper decontamination procedures have to be followed for the surfaces, equipment and persons who are contaminated which has to be avoided. An automated system will reduce human contamination as human interference is eliminated [3].

Studies have reported that collective whole-body exposure was decreased by 25% in 2 years with the use of an automated dispensing/injection system. These systems have

some disadvantages, such as high capital cost, cost of consumables, cost of multi-dose vials from off-site cyclotrons, unfamiliarity with the system, and space requirement [4][5][6].

This project aims to indigenously design and develop a prototype for a low cost open loop automated system for dispensing the radiopharmaceuticals used in nuclear medicine into syringes with a simple user interface. This would reduce the exposure while dose preparation and also decrease the chances of radioactive contamination.

II. MATERIALS AND METHODS

The aim of the project is to develop a mechanism to dispense the radiopharmaceutical from the radioactive source (100 ml vial) into the syringe (5 ml).

The automated system broadly comprises of the following:

1. A robotic arm to hold and maneuver the syringe to the desired locations for dispensing.
2. A mechanism to dispense the desired volume of the radiopharmaceutical into the syringe.

The flowchart of the various activities that are performed by the two mechanisms has been given in Fig.1

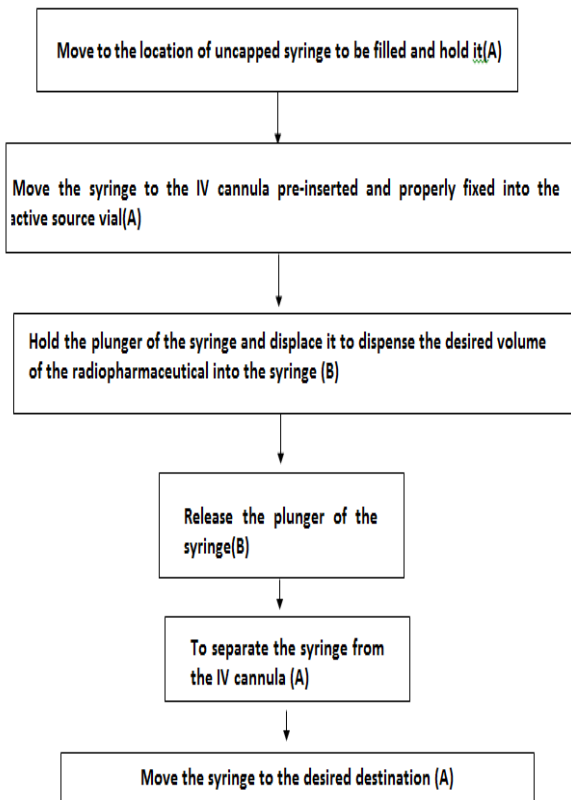


Fig.1 Flowchart of various activities performed by the mechanisms

III. DESIGN OF MECHANISMS

A. Design of Robotic ARM A

TABLE I SPECIFICATIONS OF THE ROBOTIC ARM A

Specification	Value
Number of axes	2
Horizontal reach	200 mm
Vertical Reach	300mm
Drives	3 12 V DC motors
Configuration	2 Axes plus gripper. All axes completely independent.

The robotic arm A comprises of the following components

1. Lead screw and nut
2. Base
3. Supporting rods
4. Supporting plates
5. Motor mounting
6. Gripper Arm
7. Gripper
8. Castor wheels

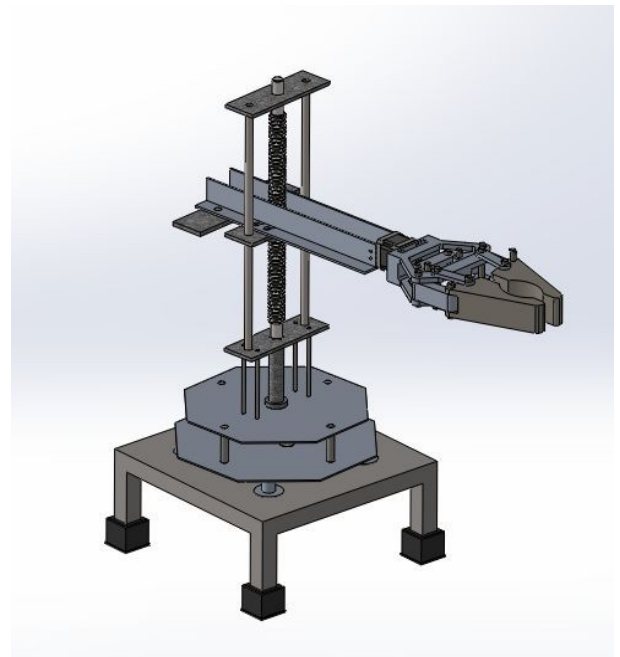


Fig .2 CAD Model of Robotic Arm A

1. Lead Screw and Nut

The lead screw and nut arrangement is used in the assembly for the gripper arm to perform vertical translator motion. The specifications are as follows.

- Total Length: 500 mm
- Total Threaded Length: 400mm
- OD : 16mm
- ID : 13mm
- Pitch of Thread : 3mm

Face Angle : 14.5°
Material : 4150 Steel (MS)
Mass : 2.95 kg.
The nut used is of bronze

2. Base

Base is made up of hollow square aluminium pipes cut and welded together to form a square shaped stand. A rubber cap is inserted at the ends of the legs which acts as a vibration isolator.

3. Supporting Rods

The lead screw is prevented from rotating by using supporting rods. The material used is stainless steel.

4. Supporting Plates

Three supporting plates are used in the assembly. Two plates are used to prevent the nut from rotating. One plate is used to connect the lead screw nut with the guide rods.

5. Motor Mounting

The motor that powers the lead screw is mounted on two galvanised sheets on top of the base is used to mount

6. Gripper Arm

Two L shaped aluminium plates of length 300 mm are used to mount the grippers. The grippers are mounted on one end with the help of 4 screws. Finite element analysis model for the same was also developed in software in order to check for the stability of the assembly.

7. Gripper

An electric gripper is used for ease of operation and handling. The gripping surface is plastic having coefficient of friction of 0.3. Power is transmitted through an assembly of two spur gears and a worm gears.

8. Castor Wheels

They are mounted between the base plate and the turn table to rotate the assembly. To ensure proper alignment, 4 castor wheels are used.

The CAD model of the arm A is provided in Fig.2

B. Design of mechanism B

The mechanism B comprises of the following components

1. Lead screw and nut
2. Base Plate
3. Guides
4. Bracket
5. Flanged coupling
6. Attachment to hold the plunger of the syringe.

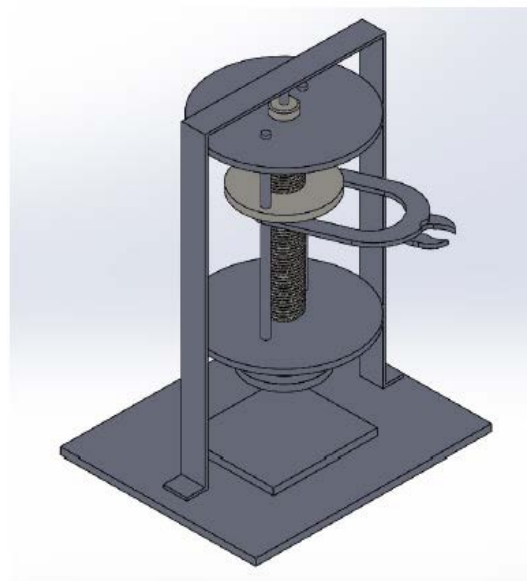


Fig. 3 CAD model of mechanism B

1. Lead screw and Nut

A lead screw and nut arrangement is used to achieve the vertical motion of the syringe plunger in order to fill the medicine. The specifications are as follows:

Material: Teflon
Total length: 127 mm
Working length: 86 mm.
Major Diameter of Lead Screw – 22mm
Minor Diameter of Lead Screw – 15.8mm
The nut is of ABS material.

2. Base Plate

The base plate is made of acrylic material. It is circular and the lead screw assembly is mounted on it.

3. Guides

Guides are used to ensure the linear movement of the nut. The material used is steel.

4. Bracket

A bracket made of acrylic material serves the purpose of the arm on which the attachment to hold the plunger is mounted.

5. Flanged Coupling

The lead screw is coupled to the motor shaft with the help of the flanged coupling..

6F. Attachment to hold the plunger

An attachment to hold the plunger is designed. It is mounted with the help of a pin join on the bracket. It is currently operated manually.

The CAD model of the mechanism B is shown in fig.3

IV. AUTOMATION AND CONTROL OF THE SYSTEM

Three 12 volt DC motors are used for gripper, lead screw and turn table movement of Robotic Arm A. 12 volt stepper motor is used for lead screw motion of the mechanism B. L298N motor drivers are used to drive the motors. Microcontroller: Arduino Mega and Arduino Uno is used to control the motion of the robot. Figure 5 gives the complete assembly. For controlling the system, a user interface has been created using VB .Net. The user can give inputs to obtain the various motions of the mechanism. It interacts with the microcontrollers. The programming in microcontrollers controls the motors through the motor driver to start and stop at the pre decided positions of the empty syringe, vial and the location where the filled syringe is to be placed. Also it is programmed to dispense 5 ml of fluid into the syringe. The microcontrollers in turn give pulses to the motor driver and thus the motor control is achieved. Figure 4 gives the user interface that was developed. The complete set up comprising of the Robotic Arm A, Mechanism B and the control system has been illustrated in fig.5

V. RESULTS AND DISCUSSION

The fabrication and assembly of the two mechanisms proposed for the prototype is completed. The automation and control using VB .Net and Arduino softwares are achieved for the two mechanisms. The mechanism A is able to move from one point to another to hold and move the syringe. Mechanism B was able to dispense by 5 ml which can be further modified to make it flexible. The complete activity was performed within a minute. The control of the mechanism is achieved from a remote location. The system is an open loop system. In future, more accurate positioning of the syringe and dispensing can be achieved by the use of image processing and feedback control system.

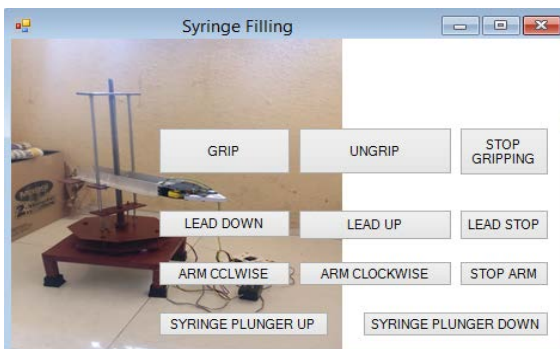


Fig 4. Graphical user interface for control

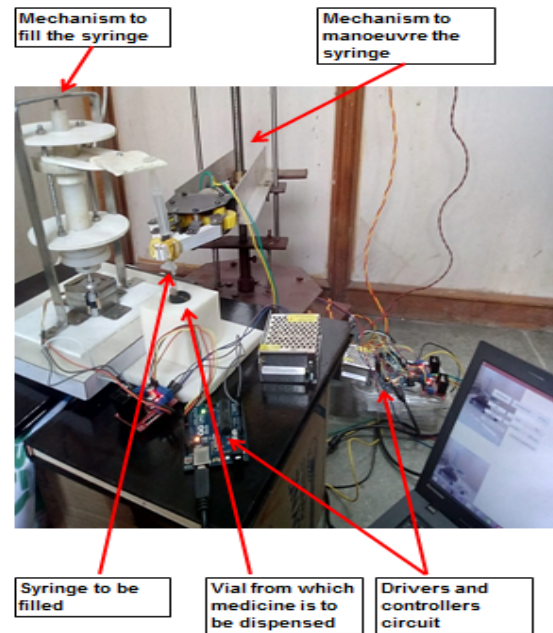


Fig. 5 The prototype of the automated syringe dispenser system

Nuclear medicine staffs handles radiopharmaceutical while preparing the individual radiopharmaceutical doses by filling the syringe and while injecting the medicine into the patients. This automated mechanism can eliminate the human involvement for filling the syringe. Thus it can reduce the time of exposure while carrying out this activity. Also chances of spillage is minimum as a result of which the radioactive contamination probability is less.

Thus the prototype has been developed which can be used for the dispensing of the radiopharmaceutical which will reduce the unwanted exposure to radiations for the nuclear medicine workers while dispensing.

VI. CONCLUSION

Prototype of an open loop automated system to dispense the radiopharmaceutical has been designed and developed. The nuclear medicine staff is exposed to the radiation during dose preparation and dose administration. This project enables to prepare the radiopharmaceutical doses remotely. As a result of which the exposure during dose preparation can be minimised

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REFERENCES

- [1] T. Donmoon, W. Chamroonrat, and M. Tuntawiroon, "Radiation exposure to nuclear medicine staffs during 18F-FDG PET/CT procedures at Ramathibodi hospital," *In Journal of Physics: Conference Series*, Vol. 694, No. 1, pp. 012061, Mar 2016.
- [2] H. Piwowarska-Bilska, B. Birkenfeld, A. Gwardyś, A. Supińska, M. H. Listewnik, B. Elbl, and K. Cichoń-Bańkowska, "Occupational exposure at the Department of Nuclear Medicine as a work environment: A 19-year follow-up," *Polish journal of radiology*, Vol.76, No.2, pp.18-21, Apr 2011.
- [3] A. Jha, A. Singh, S. Mithun, S. Shah, A. Agrawal, N. Purandare, B. Shetye, and V. Rangarajan, "Designing of high-volume PET/CT facility with optimal reduction of radiation exposure to the staff: Implementation and optimization in a tertiary health care facility in India," *World journal of nuclear medicine*, Vol.14, No.3, pp. 189-196, Sep 2015.
- [4] Alenezi and K. Soliman, "Trends in radiation protection of positron emission tomography/computed tomography imaging," *Annals of the ICRP*, Vol. 44, No. 1_suppl, pp. 259-270, 2015.
- [5] S. Robert and V. Gerbaudo, "Occupational radiation dosimetry assessment using an automated infusion device for positron-emitting radiotracers," *Journal of nuclear medicine technology*, Vol. 40, No. 4, pp. 244-248, 2015.
- [6] P. Covens, D. Berus, F. Vanhavere, and V. Caveliers. "The introduction of automated dispensing and injection during PET procedures: a step in the optimisation of extremity doses and whole-body doses of nuclear medicine staff." *Radiation protection dosimetry*, Vol. 140, No. 3, pp. 250-258, 2010.
- [7] N. Benatar, B. Cronin, and M. O'doherty. "Radiation dose rates from patients undergoing positron emission tomography: implications for technologists and waiting areas," *European journal of nuclear medicine*, Vol. 27, No. 5, pp. 583-589, Apr 2000.
- [8] T. Biran, J. Weininger, S. Malchi, R. Marciano, and R. Chisin. "Measurements of occupational exposure for a technologist performing 18F FDG PET scans," *Health physics*, Vol.87, No. 5, pp. 539-544, Nov 2004.
- [9] Chiesa, V. De Sanctis, F. Crippa, M. Schiavini, C. Fraigola, A. Boggi, C. Pascali, D. Decise, R. Marchesini, and E. Bombardieri. "Radiation dose to technicians per nuclear medicine procedure: comparison between technetium-99m, gallium-67, and iodine-131 radiotracers and fluorine-18 fluorodeoxyglucose." *European journal of nuclear medicine*, Vol. 24, No. 11, pp. 1380-1389, Nov 1997.
- [10] B. Guillet, P. Quentin, S. Waultier, M. Bourrelly, P. Pisano, and O. Mundler, "Technologist radiation exposure in routine clinical practice with 18F-FDG PET," *Journal of nuclear medicine technology*, Vol. 33, No. 3, pp. 175-179, Sep 2005.
- [11] O. Roberts, O. Fiona, H. Gunawardana, K. Pathmaraj, A. Wallace, T. Mi, S. Berlangieri, G. O'Keefe, C. Rowe, and A. Scott, "Radiation dose to PET technologists and strategies to lower occupational exposure." *Journal of nuclear medicine technology*, Vol. 33, No. 1, pp. 44-47, Mar 2005.
- [12] Robinson, J. Young, A. Wallace, and V. Ibbetson, "A study of the personal radiation dose received by nuclear medicine technologists working in a dedicated PET center," *Health physics*, Vol. 88, No. 2 Suppl, pp. S17-21, Feb 2005.
- [13] T. Seierstad, E. Strandén, K. Bjering, M. Evensen, A. Holt, H. M. Michalsen, and O. Wetteland, "Doses to nuclear technicians in a dedicated PET/CT centre utilising 18F fluorodeoxyglucose (FDG)," *Radiation protection dosimetry*, Vol.123, No. 2, pp. 246-249, Feb 2007.
- [14] P. Tandon, M. Venkatesh, and B. Bhatt, "Extremity dosimetry for radiation workers handling unsealed radionuclides in nuclear medicine departments in India," *Health physics*, Vol.92, No. 2, pp. 112-118, Feb 2007.
- [15] B. Zeff, and M. Yester, "Patient self-attenuation and technologist dose in positron emission tomography," *Medical physics*, Vol.32, No. 4, pp. 861-865, Apr 2005.