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Convolution Neural Network based Next Generation Neonatal Surgery: Innovations and Interventions in Precision surgery for New-borns

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ABSTRACT

Surgical operations carried out on newborns, usually during the first 28 days of their lives, are referred to as neonatal surgery. These operations are frequently required to treat life-threatening illnesses or congenital abnormalities (birth defects) that are discovered either before or soon after delivery. Using machine learning and deep learning, artificial intelligence can revolutionize conventional surgical techniques. One kind of artificial neural network that is particularly good at identifying patterns in visual data is the Convolutional Neural Network (CNN). It does this by employing a unique layer known as a convolutional layer, which uses a process known as convolution to learn how to extract features from the input data. Congenital lung malformations, congenital diaphragmatic hernia (CDH), intestinal atresia, necrotizing enterocolitis (NEC), and esophageal tresia /tracheoesophageal fistula (EA/TEF) are among the critical conditions that can be identified in newborns using a variety of diagnostic techniques, including clinical cases examined using plain radiographs, CT scans, prenatal ultrasounds, and magnetic resonance imaging (MR) images. CNN can accurately identify and categories the kind and degree of a newborn's condition. The evaluation of several CNN-based advanced procedures for newborns, together with their difficulties and potential developments, is the main emphasis of this study.

Keywords: Convolution Neural Network (CNN), Deep Learning, Congenital Diaphragmatic Hernia (CDH), Congenital Lung Malformations (CLM)

1. INTRODUCTION

New-borns who are premature and in critical condition may require surgery shortly after delivery to correct malformations or abnormalities. It takes extremely specialised care to operate on these vital new-borns. The following conditions are common ones that need surgery. Congenital diaphragmatic hernia (CDH) is a diaphragmatic abnormality that permits organs from the abdomen to enter the chest cavity. Esophageal atresia/tracheoesophageal fistula (EA/TEF) is the term used to describe an irregular or discontinuity between the esophagus and trachea. The conditions known as Gastroschisis and omphalocele are abnormalities of the abdominal wall in which the intestines or other organs protrude outside the body. Blockage or lack of a section of the intestine is known as intestinal atresia. One severe intestinal condition that frequently necessitates colon resection is Necrotising Enterocolitis (NEC). A disorder called Hirschsprung's disease causes severe constipation or blockage in areas of the colon where nerve cells are absent. Surgery is necessary right away for congenital cardiac abnormalities (e.g., transposition of the major arteries).

Deep learning models have been used in medicine in recent years to quickly diagnose a wide range of illnesses. The majority of research in this field focusses on either adult or juvenile patients. Deep learning research unlocks new perceptions for diagnosing illnesses in neonates. Additionally, early and precise detection of respiratory infections in neonates is essential because it is well known that respiratory conditions like pneumonia rank highly among the causes of neonatal mortality [1]. Therefore, in order to reduce the infant mortality rate, it is crucial to identify and diagnose these conditions in neonates. The most prevalent condition affecting infants is congenital lung malformations (CLMs), a collection of developmental abnormalities that impact the blood vessels, airways, and parenchyma of the lung. They can take many different forms and are brought on by aberrant lung growth during the final stages of life. Another common condition in new-borns is congenital diaphragmatic hernia (CDH), a birth defect in which the diaphragm, the muscle that separates the chest and belly, fails to close completely, leaving a hole that permits abdominal organs to enter the chest cavity. Lung issues and breathing difficulties are only two of the concerns that may result from this. This study demonstrates several methods for CNN-based illness identification.

Convolutional neural network (or CNN) is highly motivated by the visual system of living beings, as well as it is a special type of multilayer neural network or deep learning architecture. The CNN works well in a variety of computer vision and natural language processing domains. A conventional convolutional neural network comprises of one or more blocks of convolution and pooling layers, one or more fully connected (FC) layers, and an output layer. Learning feature representations of the input is the goal of the convolution layer. Several learnable convolution kernels or filters, which are used to calculate various feature maps, make up the convolutional layer. Every feature map unit is linked to a receptive field in the layer above. The input is convolved using the kernels, and the elementwise non-linear activation function is used to the convolved result to create the new feature map. The convolutional layer's parameter sharing feature lowers the complexity of the model. To create a single output, the pooling or sub-sampling layer down samples a tiny portion of the convolutional output. There are other subsampling methods, such as average pooling, min pooling, and max pooling. Pooling makes the network translation invariant and minimises the amount of parameters that need to be calculated. The last component of CNN is essentially composed of one or more feedforward neural network (FC) layers. The final CNN output is produced by the FC layer using input from the final pooling or convolutional layer. Figure 1 illustrate the fundamental architecture of CNN [2].

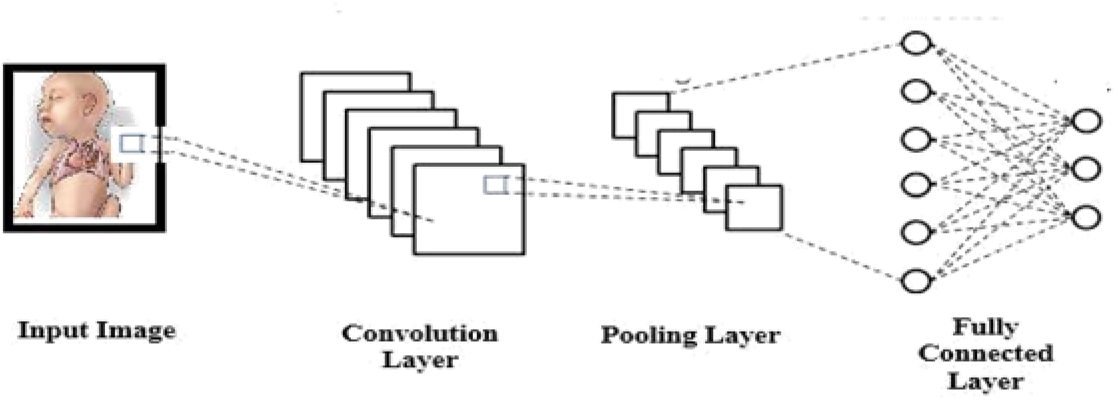

Figure 1: Basic architecture of Convolution Neural Network [2]

CNN is capable of achieving cutting-edge results in a number of areas, including speech and natural language processing, visual question answering, object tracking, object detection, segmentation, human pose estimation, text detection, visual saliency detection, action recognition, scene labelling, and image classification [2].

2. CNN DRIVEN IMAGING AND DIAGNOSTIC FOR CONGENITAL DIAPHRAGMATIC HERNIA AND CONGENITAL LUNG MALFORMATIONS

A diaphragmatic defect that permits the herniation of the abdominal organs into the thorax is the hallmark of Congenital Diaphragmatic Hernia (CDH), a rare congenital deformity that affects 1–4 neonates out of every 10,000 live births [3]. Pulmonary hypoplasia and postnatal pulmonary hypertension (PH) are characteristics of CDH. Reduced gas-exchange surface area and decreased bronchial branching are always linked to defective vascular development, which is typified by altered vasoreactivity and less vascular network extension and remodelling. PH has been the primary focus of the neonatal health research. According to clinical and echocardiographic criteria, PH in the context of CDH is characterised as increased pulmonary vascular resistance in relation to systemic blood pressure. But the exact pathophysiology of PH is still unknown. Furthermore, one of the most important factors influencing prognosis is the extent of postnatal respiratory and circulatory impairment [3]. Neonatal survival is roughly 70%, but depending on a number of variables, including defect location and size, concomitant malformations, gestational age at birth, and treatment, it can range from over 90% in mild cases of CDH to less than 10% in severe types [3].

Corrective prenatal intervention is possible when fetuses with low survival rates are identified early. Fetal endoscopic tracheal occlusion (FETO), which is carried out at 27–29 weeks using an endovascular detachable latex balloon, does, in fact, prevent abdominal organ herniation and encourage lung growth by accumulating lung fluid, thereby increasing survival [3].

A new framework for predicting congenital diaphragmatic hernia in a newborn baby has been suggested by Ilaria A. et al. (2021) and is based on a combination of machine learning and deep learning techniques [3]. Their suggested method finds pregnant patients and adds them to the data collection process. Mothers at less than 30+6 weeks of GA singleton pregnancy are included. Imaging information from clinical prenatal and postnatal parents' chest radiographs and foetal MRIs is gathered and fed into a suggested model to predict CDH traits. This process is illustrated in Figure 2 [3].

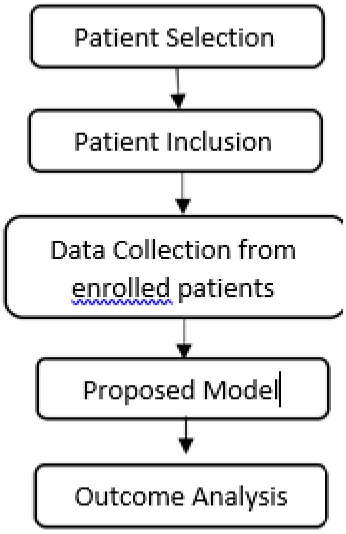

Figure 2: Methodology for prediction of CDH [3]

The computational approach is predicated on the multivariate and combined use of variables from prenatal and postnatal clinical and instrumental data. Using commercial software or, ideally, open-source libraries, an ad-hoc computing tools were developed for the analysis of MRI images. It can do the following tasks: import the native image, (semi)automatic contouring and segmentation of the volumes of interest, compute semantic and agnostic feature descriptors, and classify using ML and DL methods. Following contouring and segmentation, feature descriptors have been computed in the volumes of interest for supervised pattern recognition using machine learning techniques. Because of its exceptional performance, the fully linked Convolution Neural Network known as 3D U-Net has been employed for volumetric segmentation in medical pictures.

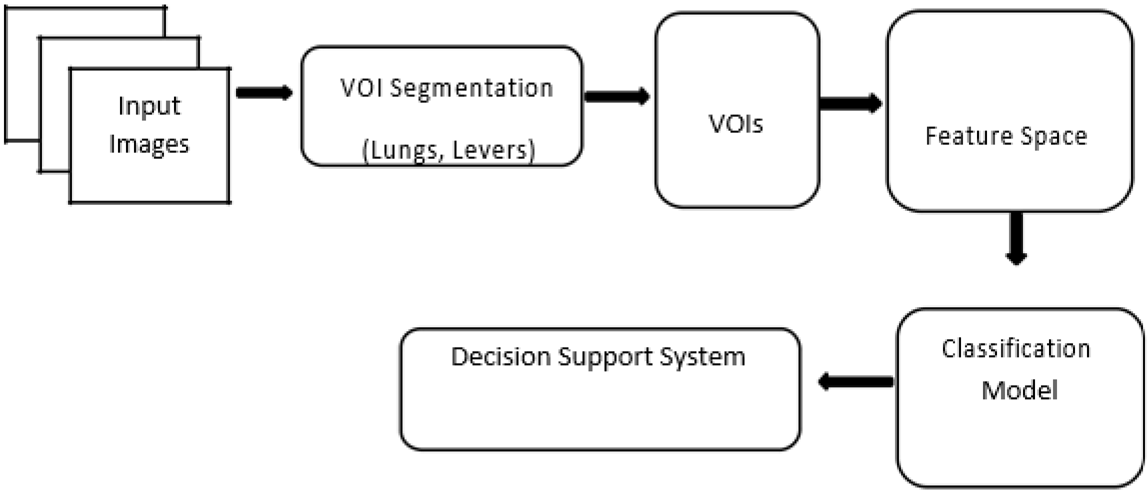

Figure 3: The architecture for the prediction of CDH [3].

The radiomic procedure is depicted in the flowchart, beginning with multimodal image acquisition. Following the segmentation or contouring of the volumes of interest (such as the liver and lungs of a fetus) either manually or (semi)automatically, feature descriptors arecomputed from the form and texture of the VOI. The resulting feature vectors are labelled with pertinent output variables (such as the presence of postnatal PH or the need for ECMO, among others) along with a selection of prenatal clinical parameters. Following dimensionality reduction to eliminate superfluous and redundant descriptors, the supervised classification/regression model-construction process begins. Leave-one-out cross-validation (LOO-CV) has been used to train and validate the model. The pipeline output that will be used in the Decision Support System is the trained and verified machine learning model [3]. CNN-based predictive algorithms will be crucial for accurate outcome prediction, early targeted therapies, and individualised care of fetuses and new-borns with congenital heart disease.

Neonatal morbidity and mortality are thought to be mostly caused by disorders of the respiratory system. CNN-based CLM in neonatal detection has been proposed by Amodeo I. et al. (2021) [4]. One noteworthy non-ionizing technique is thermal imaging, and medical diagnostics use thermal symmetry or temperature change monitoring. Using an infrared camera, thermal images were captured and recorded using an IRBIS user interface in order to generate a dataset [4]. Thermal camera applications and portable computers have been used to convert thermograms into raw RGB images. To identify respiratory system abnormalities in neonates, CNN model and data enhancement techniques were applied. Neonates with different pulmonary abnormalities are in the first class of the classification, whereas neonates with other disorders (such as cardiovascular or abdominal diseases) are in the second class. 20 photos from each new-born and 680 photos of 34 neonates with 16 lung disorders and 18 other diseases were used for classification in the study's first section. In the second section, 2060 photographs were used for categorisation, utilising all of the infants' photos as well as photos acquired using various augmentation approaches [4]. Figure 4 illustrate the CNN based detection of CLM in neonates.

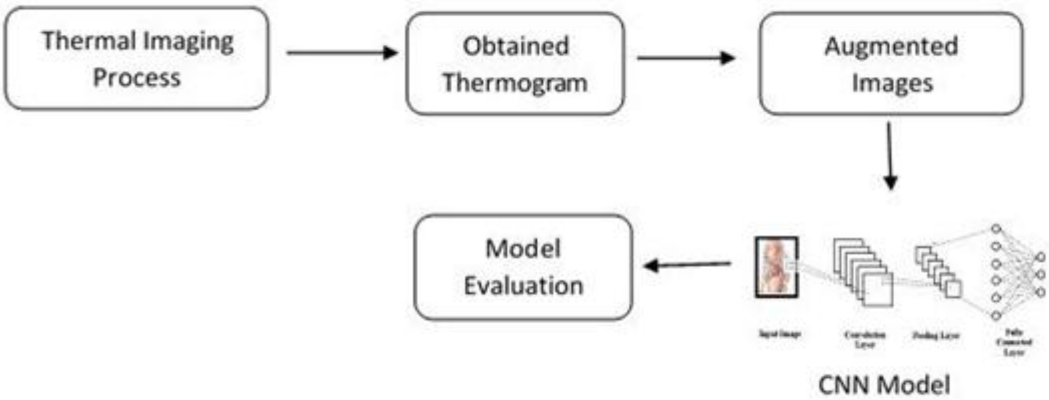

Figure 4: Architecture to detect neonatal respiratory system anomalies [4]

Eighty-four percent specificity, eighty-five percent sensitivity, and eighty-five percent accuracy were the outcomes of the original limited dataset evaluation. All assessment metrics values of the enlarged dataset results increased when the number of thermal images was increased from 680 to 2060. For instance, the test's sensitivity was determined to be 100%, while its accuracy metric increased from 85% to 91% [4].

3. INTERVENTIONS AND INNOVATIONS IN PRECISION SURGERY

Neonatal surgery presents unique challenges due to the small size, fragility, and developmental considerations of infants. Various challenges of neonatal surgery are as follows.

Neonates have enormously minor, delicate organs and blood vessels, making precision critical. Hence, there is a far greater chance of bleeding, tissue injury, and technical mistakes.

Anaesthesia and recuperation are made more difficult by underdeveloped lungs, liver, kidneys, and immune systems, which are also more susceptible to stress and infection.

The amount of abnormalities may not be fully revealed by prenatal imaging. It can be challenging to decide when to operate; while early surgery may save lives, it is also dangerous.

Complications of anaesthesia, such as apnoea and cardiovascular instability, are more likely to affect new-borns.

Many surgical instruments are not made with new-born anatomy in mind. The anatomy of new-borns is not well-suited for many surgical instruments.

In recent years, revolutionary advancements in precision surgery have been made in the very accurate customisation of surgical procedures for each patient. These developments are meant to promote long-term health, lessen difficulties, and enhance results. The healthcare sector is being revolutionised by deep learning algorithms and artificial intelligence. Various innovations are

Laparoscopic and Thoracoscopic techniques are examples of minimally invasive and image-guided surgery, and intraoperative imaging can improve on conventionally performed, imprecise surgical procedures.

Robotic-Assisted Surgery can improve magnification vision, tremor filtration, and dexterity.

Surgeons can practise intricate procedures with the help of 3D printing and surgical planning.

Artificial Intelligence and Decision support enhances the precision of diagnosis and directs surgical choices.

4. CONCLUSION

Precision-based technologies are being incorporated into neonatal surgery, which is rapidly changing the field. Advances in genetics, AI, robotics, and image-guided therapies are raising the bar for safety, efficacy, and customisation. In order to advance these revolutionary methods and enhance results for the most vulnerable patients, CNN, a sort of Deep Learning methodology, can play a crucial role. Integration of various Pretrained DL models in surgical procedures can improves prediction of Congenital Diaphragmatic Hernia and Congenital lung malformations in order to mitigate death rate in neonates.

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