Ian Donald

Investigating the use of ultrasound technology For obstetric monitoring

by
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Contents

Plan

In this project I aim to discover:

- Who is responsible for the development of ultrasound scanning during pregnancy?
- When this application of ultrasound was discovered?
- Why was this application of ultrasound developed?
- What can be detected using ultrasound technology
- The background to the person responsible for this discovery, what other work have they done or been involved in?
- Names of other scientists who contributed to the research and what their contributions were
- How this discovery has been of benefit to society

There are many possible sources of data for my research. I will primarily be using the internet and books. I shall also be consulting any relevant academic journals.

There are two main questions that I hope will be answered by this report. These are:

1. Why was it necessary to develop ultrasound technology for use in the medical field, specifically why was it developed for monitoring pregnancy?

2. How has this application of ultrasound been of benefit to society?

I have set myself an approximate timescale which is as follows:

Before 30/09/07 I shall choose my subject area and “Hero”.
Once this has been chosen I can start my research.
Before 30/11/07 I would ideally have all of my research completed, I will select all relevant information and begin to report my findings.
Before 31/12/07 I would like to have the 1st draft ready to be submitted.
By 22/01/08 the final draft will be ready for submission.

Introduction

Professor Ian Donald was a pioneer of his time. Although ultrasound technology was already in use in both the military and in the field of medicine, he was the first to develop its use for foetal imaging. This application of ultrasound technology was first discovered during his time researching at Glasgow University.

Professor Ian Donald received many honours in recognition of his work and his discovery has led to ultrasound being routinely used to monitor an unborn baby's development in the womb.

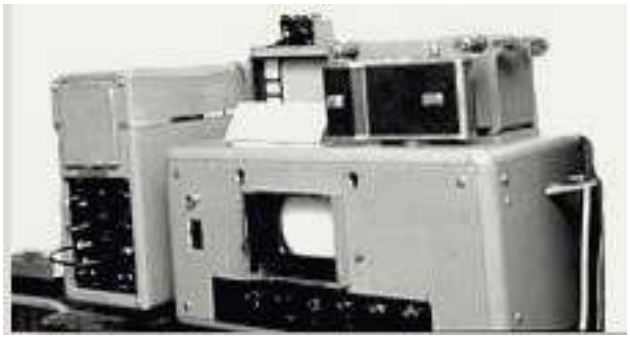
This report will discuss Professor Ian Donald's findings and the implications that his work has had within society.

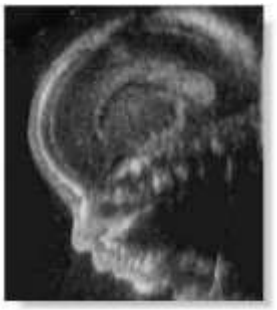
Ultrasound scanning during pregnancy is now a routine test, but it hasn't always been this way.
The application of ultrasound technology to monitor foetal development during pregnancy was not used until the 1950s when Professor Ian Donald discovered this use. Before this the only way to accurately diagnose the condition of a foetus was through surgery, which was invasive and posed risks to both mother and baby. The other alternative was to use x-ray radiation but this led to a high rate of leukaemia amongst children who had been exposed in utero.

Professor Ian Donald is well known as the inventor of obstetric ultrasonography; he was extremely well educated and has won many awards in recognition of his work.

The professor was born on 27th December 1910 in Liskeard Cornwall; he was however educated at Warriston School in Moffat and then went on to study at Fettes College in Edinburgh.
After this his family moved to South Africa, where he graduated with a BA in French, Greek, English and Music from Diocesan College in Cape Town. He then progressed to study medicine at the University of London and was awarded an MB BS in 1937.
He followed his education by working as a medical officer in the RAFVR from 1942 – 1946, during his service he was awarded an MBE for rescuing airmen from a burning aircraft.
He was a keen and energetic sailor; he had many interests including painting boats and music. In his younger days he built boats as a hobby.

In 1951 professor Ian Donald became Reader in Obstetrics and Gynaecology at St Thomas Hospital Medical School. He received a research scholarship from the Royal College of Obstetricians and Gynaecologists to carry out research into neonatal respiration. He gave the Blair Bell memorial lecture on this subject in 1954.
In this same year he accepted the Regius Chair of Midwifery at Glasgow University; he took with him what remained of his grant and his knowledge of radar and echo sounding and began to develop ultrasound for use during pregnancy.
It was whilst researching at Glasgow University that he met a man named Tom Brown. Tom was a local shipping engineer with Kelvin Hughes Electronics Corporation, and together they developed the first B-type scanner, which was capable of detecting echoes from the head of an unborn baby (see images on next page).





During his career, Professor Ian Donald was awarded all of these awards:

- Eardley Holland gold medal
- Blair Bell gold medal
- Victor Bonney prize
- Honorary Dsc at both London and Glasgow University
- CBE 1973
- Honorary FRCR 1983, in 1984 he was made an honorary member along with Tom Brown
- Honorary fellowship at the Royal College of Physicians of London only 2 weeks before he sadly passed away.

Professor Ian Donald never shunned his responsibilities as a doctor and a teacher despite all the research he was conducting. He always gave his patients his full attention and gave a great deal of enthusiasm in his lectures to his students.
As well as being a doctor, a teacher and a researcher he was the author of Practical Obstetric Problems (5 editions in print) and also Investigations of Abdominal Masses by Pulsed Ultrasound, which was published in the Lancet on June 7th 1958.
He also supervised the planning and design of the Queen Mothers Hospital that opened in 1964.

Professor Ian Donald sadly died on 19th June 1987 at his home in Paglesham Essex; throughout his life he had been plagued by ill health and had undergone major cardiac surgery on three occasions. He left behind his wife, Alix, four daughters and thirteen grandchildren.

In honour of the professor a school of medical ultrasound was founded. The Ian Donald Inter-University School of Medical Ultrasound in Dubrovnik, Croatia was started by Professor Asim Kurjak in 1981. The Ian Donald gold medal is awarded each year by the International Society of Ultrasound in Obstetrics and gynaecology (ISUOG) to the person whose work has the most profound influence in the development of obstetrical and gynaecological ultrasonography.

Ultrasound

Ultrasound is a diagnostic imaging technique, used to visualise muscles and the internal organs of the body using echo sounding. It can be utilised to accurately measure the size and structure of internal organs and will also show any abnormalities such as lesions.

Ultrasound has many uses in the medical field including but not limited to:

Therapeutic uses such as:

- Taking biopsies
- Guiding needles for fluid drainage
- Breaking up kidney stones and other stones formed within the body.

Diagnostic uses in the fields of:

- Cardiology
- Endocrinology
- Gastroenterology
- Ophthalmology
- Urology
- Musculoskeletal medicine
- Vascular medicine
- Intra vascular medicine
- Interventional medicine
- Gynaecology
- Obstetrics

The reason ultrasound is used in so many disciplines is because it gives effective imaging of the soft tissues in the body. The frequency of ultrasound wave used depends upon which area of the body is to be investigated. Muscles, tendons, testes, breasts and the neonatal brain need a high frequency, usually between 7-18 MHz. The higher frequency gives a better resolution picture. In comparison the liver and kidneys need a lower frequency of 1-6 MHz, which will give a poorer picture but enables greater penetration into the body.

The image produced by ultrasound is usually in 2D and is a greyscale image, although newer technology has enabled 3D and 4D real time images to be produced. The sound waves echo from solid structures such as bone as well as from small structures in organs, and are reflected back to a transducer. The transducer converts the sound waves into pulses of energy that are used to construct a digital image on a screen.
The greyscale image shows three different things:
White- where there has been a strong echo
Black- where there has been a weak echo
Grey- everything in-between

The application of ultrasound that I will concentrate on is its use in obstetrics and gynaecology.

An obstetrical ultrasound is used during pregnancy to do a number of tests on an unborn baby. These include:

- To check the development of the baby and the placenta
- To measure the volume of amniotic fluid surrounding the baby
- For accurate dating of the pregnancy
- To detect multiple pregnancies
- To indicate major defects in the heart, brain, spine and kidneys
- Measurement of the skin fold of the neck which could indicate Downs Syndrome
- To locate the position of the baby during invasive procedures such as Chorionic Villus sampling and Amniocentesis

If a possible abnormality is detected from an ultrasound scan then the option of termination of the pregnancy can be explored. This is obviously an extremely difficult decision to make and the ultrasound could have misdiagnosed when there is no abnormality.

Ultrasound scans are generally considered to be safe although some slight apparently detrimental effects have been observed. They should therefore only be performed where there is a valid medical indication and the lowest exposure possible should be used to achieve the diagnosis.

There have been two studies carried out into the safety of ultrasound:
A study at Yale Medical School showed that frequent and prolonged exposure to ultrasound showed abnormal neuronal migration in mice
A study at the Karolinska institute in Stockholm showed that there could be a possible link between the number of scans received by male foetuses and left-handedness.

There is a distinct lack of data on the long-term outcomes such as the implications on neurodevelopment. It is therefore it is regulated in the USA by FDA-guidelines that have been accepted worldwide.

Below are images of A. a modern scanner and B. a linear array transducer used together to produce the image of a foetus.

A

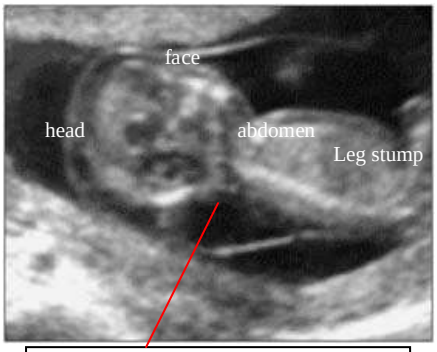
B

There is statistical information available that backs up the use of ultrasound as a diagnostic tool during pregnancy. For example:

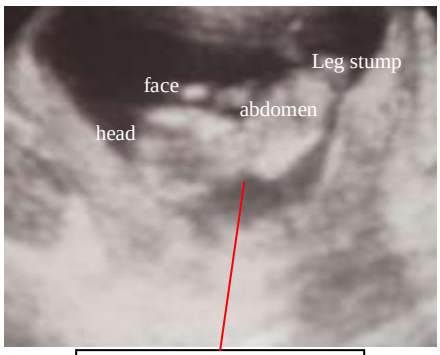
Outcome in 4116 pregnancies with increased foetal nuchal translucency in The Foetal Medicine Foundation Project22

Nuchal translucency (mm)	*Total*	*Termination (abnormal)*	*Prenatal death*	*Postnatal death*	*Alive*
95th–3.4	3423	49 (36)	47	29	3298 (96.3%)
3.5–4.4	448	23 (14)	9	4	412 (92.0%)
4.5–5.4	138	13 (8)	4	3	118 (85.5%)
5.5–6.4	48	13 (7)	4	0	31 (64.6%)
≥ 6.5	59	21 (12)	10	2	26 (44.4%)
Total	4116	119 (77)	74	38	3885 (94.4%)

This table was taken from the source http://www.Centrus.com and shows the outcomes of over 4000 pregnancies where increased foetal nuchal translucency was detected at the scan. It is clear from the table that a number of parents are unwilling to accept the risk of an abnormality and choose instead to have a termination.
The image below compares a “normal” scan result to a scan showing increased nuchal translucency. The normal scan result is on the right hand side, the scan showing the abnormality is the image on the left.



Area of increased nuchal translucency



Normal nuchal translucency

It is fairly difficult to the untrained eye but to a sonographer the increased nuchal translucency would be quite obvious. This diagnosis would lead on to more invasive, voluntary tests being carried out such as chorionic villus sampling or amniocentesis which would give a definitive diagnosis.

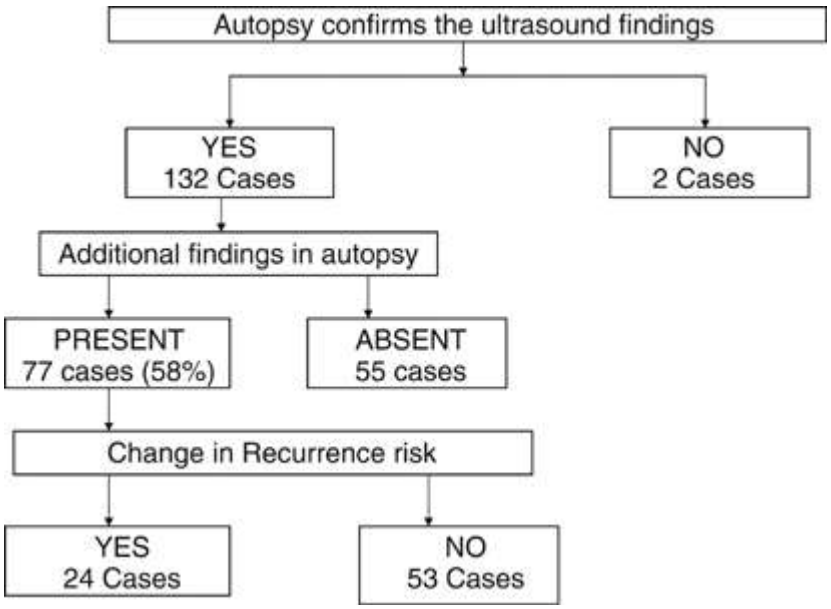
There are several conditions associated with increased nuchal translucency, these are summarised in the following table:

Table 5 Conditions associated with increased nuchal translucency

Cardiac defects Diaphragmatic hernia Exomphalos Achondrogenesis type II Achondroplasia Asphyxiating thoracic dystrophy Beckwith-Wiedemann syndrome Blomstrand osteochondrodysplasia Body Stalk anomaly Campomelic dysplasia EEC syndrome Foetal akinesia deformation sequence Fryn syndrome GM1-gangliosidosis Hydrolethalus syndrome	Jarcho-Levin syndrome Joubert syndrome Meckel-Gruber syndrome Nance-Sweeney syndrome Noonan syndrome Osteogenesis imperfecta type II Perlman syndrome Roberts syndrome Short-rib polydactily syndrome Smith-Lemli-Optiz syndrome Spinal muscular atrophy type 1 Thanatophoric dysplasia Trigonocephaly 'C' syndrome VACTEREL association Zellweger syndrome

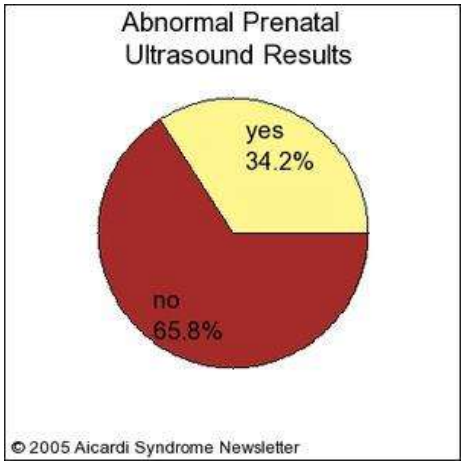
ECC syndrome, ectrodactyly-ectodermal dysplasia-cleft palate syndrome

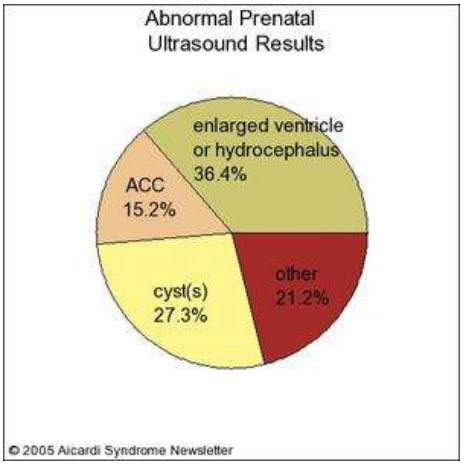
In cases where the parents have chosen to abort, the child has been stillborn or died shortly after birth a post mortem examination has been carried out. The chart below indicates how many autopsy results confirm the diagnosis from the ultrasound scan result.



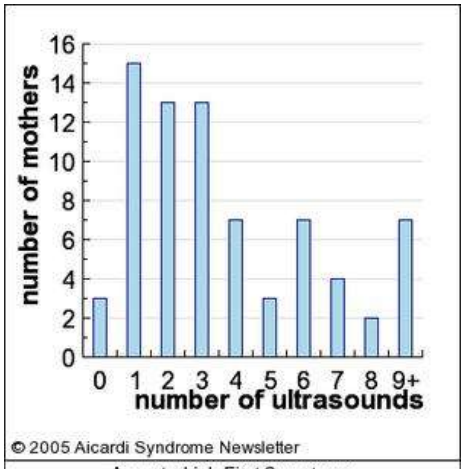
This chart indicates that ultrasound scans are a very accurate method of diagnosis although some errors can be made. No diagnosis by ultrasound scan can be 100% accurate.

Another abnormality that can be detected using ultrasound is Aicardi syndrome although the syndrome itself cannot be detected; many abnormalities may show up on the ultrasound scan. The pie charts below show the percentage of scans that detected an abnormality and also what the abnormality was.

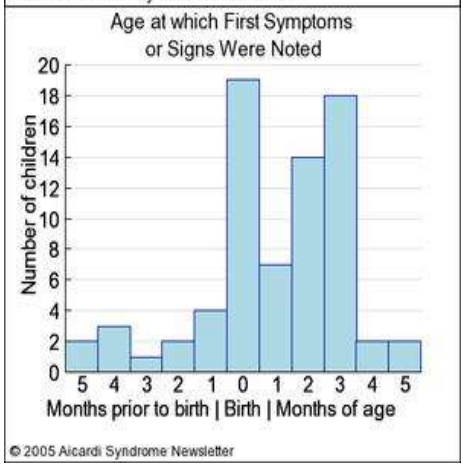


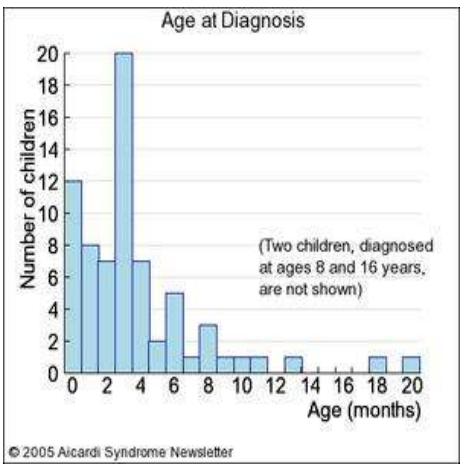


Aicardi syndrome is a neurodevelopmental disorder that affects monozygotic twins. It is a case of twin to twin transfusion where one twin fails to develop proper brain and thoracic structures, the other twin usually develops normally.



The chart shows how many ultrasound scans where received by the mothers included in the study. By comparing this chart to the pie charts above, it is obvious that the syndrome had been missed in many cases. The two charts below show that the majority of cases were not diagnosed until after the child had been born.





In many cases the child survived but would suffer ill health and was slow to reach developmental milestones.

The abortion risk of prenatal scans

Developments in ultrasound technology have meant that more abnormalities can be detected, however it is important to remember that they are not 100% accurate. The results can sometimes be misleading and cause parents to abort a healthy baby.

A six year study was carried out at Oxford's John Radcliffe Hospital which found that ultrasound can detect 68% of congenital anomalies which would lead to miscarriage or other problems. The study showed that an average of only 55% of abnormalities where correctly identified from the scan, including problems such as spina bifida and Down's syndrome.
In the final three years of the study the rate improved to 68%.

It was also shown that a small percentage of the scans showed signs of abnormalities in babies who were perfectly healthy. The researchers studied over 30,000 babies and only found 725 to be abnormal on delivery. A further 174 babies had signs of an abnormality but were normal at birth; this is a "false positive". Over 90% of these signs are what's called "soft markers", for example increased nuchal translucency which can be an indicator for Downs's syndrome.
In two of these cases parents opted for an abortion only to find out at post mortem that their babies were perfectly healthy.

More research needs to be carried out into the impact of so called "soft markers" to try and determine if the benefits of reporting them outweigh the harm that can be done when parents abort a normal foetus in fear of deformities

Peter Moore is a British prenatal expert, he is of the opinion that ultrasound is not usually a good diagnostic tool as there is no surety that a baby will be born with an abnormality it can only predict a probability.

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http://inventors.about.com/library/inventors/blultrasound.htm?p=1	17/09/2007
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http://www.unhinderedliving.com/pultra.html	04/12/2007
http://www.Centrus.com	

Other Sources:

Complete Women's Health
Royal College of Obstetricians and Gynaecologists
Dr Mary Ann Lumsden (MD, FRCOG) and Dr Martha Hickey (MD, MRCOG)

Conclusion

From this project I aimed to discover the reasons behind ultrasound being developed for use in the field of medicine, in particular for obstetrical uses. I also wanted to research what the benefits have been for society.
The research that I undertook has assisted me greatly in answering these questions as well as some other relevant question.

There was an obvious need for the technology to be developed; the previous methods of assessing the condition of an unborn child were drastic and extremely risky as they involved surgery and desperately required updating. Professor Ian Donald was extremely unimpressed with the existing diagnostic methods and set out to revolutionise obstetrics.

The professor was also heavily involved in researching neonatal respiration and developed a machine that assisted respiration in the newborn. The rest of his career was dedicated to ultrasonics.

Without the contributions of Tom Brown the technology may not have been available for many more years, he had an extensive knowledge of engineering which made the process of building the scanners possible.

Various abnormalities of the foetus can be shown on an ultrasound scan such as cardiac defects or spina bifida as well as chromosomal issues such as Down's syndrome and Edwards syndrome. Ultrasound scans can only identify an increased risk of some abnormalities and so further more invasive tests are carried out at the request of the parents. These tests will give a definite diagnosis, which gives the parents an informed choice about whether or not to continue the pregnancy.

As a diagnostic tool, ultrasound has its uses. It however also has limitations and it is impossible to be 100% certain of any given diagnosis without further tests.

There are many benefits to society since the invention of ultrasound:

- It gives parents an opportunity to see their unborn child
- It gives a clearer picture of the child's development
- It has saved many lives that would have been lost due to invasive surgical diagnosis
- It can assist in further tests such as chorionic villus sampling to guide the needle
- It can be an aid in the decision to terminate a pregnancy

In general it appears that the invention of ultrasound was a good use of the available technology, however due to its limitations it needs to be improved.

Evaluation

This project has been very challenging but also informative. I knew a fair amount about the subject before I started researching and did not expect to find out much more other than who the inventor was and a bit of background history on him.
I was surprised to find out so much more than I was told during my pregnancy, I did not realise what the sonographer was particularly checking for just that she was looking for possible problems.

My opinion on ultrasound is that it is perfect for looking into the womb as an initial test but it cannot show every possible outcome. The risk of misdiagnosis is too high and more tests need to be offered if there is a suspicion of any anomaly.
As the first opportunity to see and fall in love with your unborn baby it is the best invention possible!

If I had the chance to start the project again I would probably choose my websites more carefully. There is an awful lot of information about ultrasound and so much of it was of no relevance to me. It took too much time to look at each piece of information and decide upon its relevance. I also collected too much data on many of the birth defects and had to leave it out because it would have been too much!

I am pleased that this was the subject I chose and I still believe that Professor Ian Donald is a hero of science.