A-SCAN ULTRASONOGRAPHY

IN OPTOMETRY

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Because of the current primary care scope of practice for Optometry, pre-operative cataract workups (including axial length measurement and intraocular lens calculation), can be performed by Optometrists to fully meet the needs of their patients prior to surgery. Twenty pre-operative workups of this type were performed and the results will be included in this report, as well as an estimate of the financial benefits that can be expected from this type of care. A-Scan information will also be included as a means of providing a base line of information needed to perform A-Scan measurements and IOL calculations.

The most frequent use of an A-Scan ultrasound is in the determination of axial length of an eye prior to surgery. This information is needed to calculate the power of the intraocular lens needed for implant after the cataractous lens has been removed. Other possible uses for A-Scan include measuring corneal thickness, pre-operative scanning of both eyes to evaluate similarities and differences, post-operative verification of axial length, post-operative determination of anterior chamber depth, verification of aphakic spectacle refraction and documentation of eye growth patterns. It will be the intention of this project to concentrate on the use of A-Scan as a measurement for axial length prior to cataract surgery.

Diagnostic ultrasound is a soundbeam usually of a frequency near 10 mhz traveling at a velocity of approximately 1600 meters per second. The speed and frequency of the sound beam needs to be known to accurately determine what is being measured. The sound beam is sent from the A-Scan instrument through a probe similar to a Goldmann tonometer into the eye. The beams of sound get reflected back to the instrument from the various surfaces encountered, where they are processed and displayed on a screen for assessment by the examiner.

Although no two instruments look alike, all ultrasound units are composed of very similar components and work in the same fundamental way. The features performing the same functions in all devices are: The probe, a pulse emitter, receiver, amplifier, signal processor, display unit and image documentation.[1] A fabricated design would then appear as in figure 1.

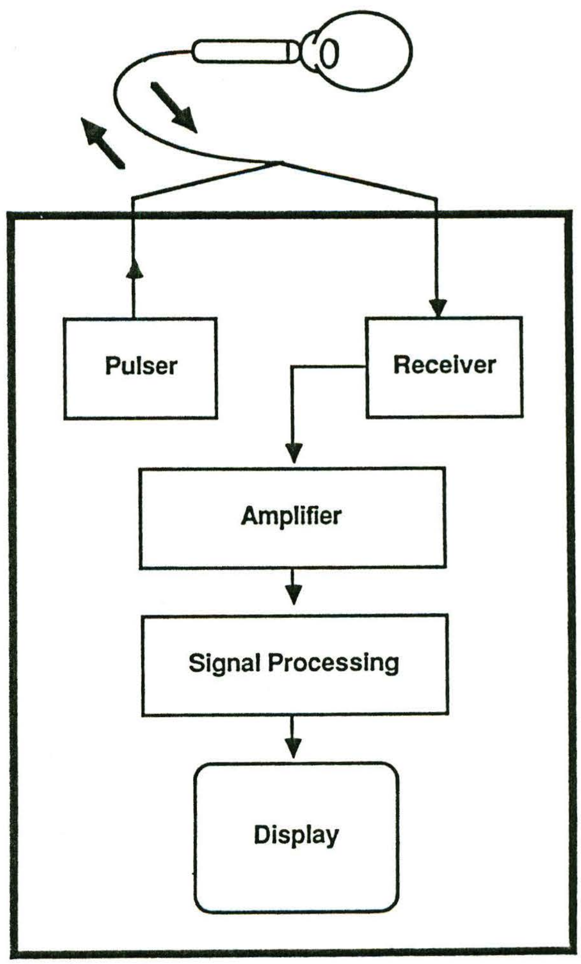


Figure 1 The fundamental components of any ultrasound device are a pulse emitter that sends electricity to the probe, a receiver to "hear" the echoes, an amplifier to enlarge them, a signal processor for reshaping, and a display for viewing the images.

(from Ophthalmic Echography, p.36)

Common to all ultrasound probes is the transducer which is a crystal capable of transforming electrical energy into sound energy. The transducer also transforms the sound energy received back into electrical energy to be amplified, processed and displayed by the ultrasound unit. A pulse emitter is part of the unit responsible for producing an electrical signal that the transducer converts into sound waves. During brief periods when the pulse emitter is not sending signals, the receiver is receiving the signals returned by the transducer once they are converted back into electrical energy. After collecting this information, the receiver sends the information to the amplifier which enlarges or amplifies the echo signals before sending them to the processor. The signal processor puts this electrical energy into analog or digital display (depending on the type of A-Scan unit) that is composed of peaks and baselines to be displayed on the screen.[1]

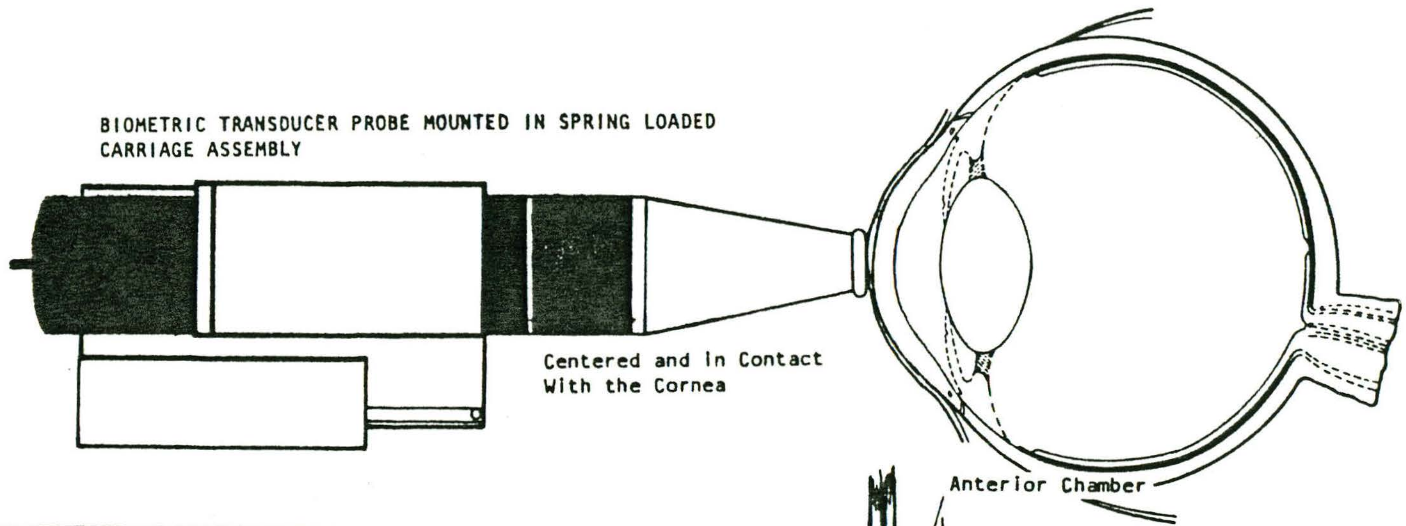
One's choice of instrument depends on the preference of the smooth rounded analog processed echoes or the squared off digitally processed echoes. The choice depends on the utilization of ones method for performing the examination, as there are no significant differences in the results obtained with the different processors.

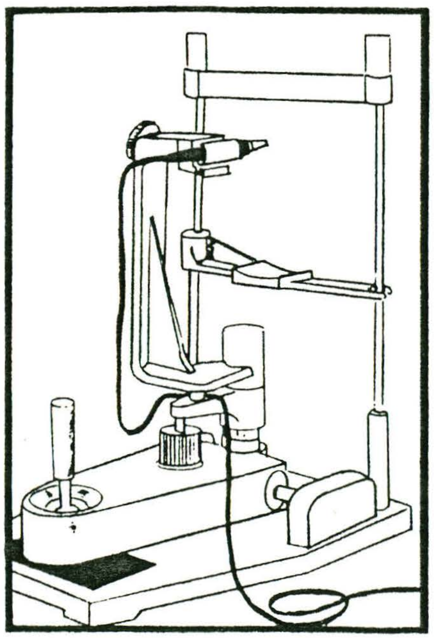
Most units have display screens for observing the echo pattern produced during the performance of an A-Scan measurement. It is recommended that during the actual measurement process, the examiner actively observes the screen to determine the accuracy and validity of each A-Scan measurement. The visual interpretation of the scan tells the examiner whether or not a reliable scan is being received by the ultrasound unit. Previous knowledge of where to expect echoes and the size expected gives the examiner a great deal of help in achieving accurate and consistent results. Therefore one should observe the display screen to interpret whether or not each scan is reliable. Results are then determined from averages of five or six scans or from a few identical scans.

In the evaluation of an A-Scan, we are concerned with the echoes produced from the reflected sound waves contacting the various ocular structures. The echoes are comprised of peaks and baselines. For measurement purposes, the width, height and distance between these peaks is the information necessary to complete the A-Scan.[1] Typical echoes are produced when the sound beam is reflected by the cornea, anterior and posterior lens, the retina, sclera and orbital fat. A sample scan is provided in figure 2. (see next page) Thus, an A-Scan is a single dimensional display from which a judgment of axial length is determined from the pattern of the echoes appearing on the screen. The axial length is usually determined by the instrument and is the distance between the corneal echo and the retinal echo.

Requirements of a phakic scan include: 1)Tall corneal echoes, 2)Tall echoes from anterior and posterior lens, 3)A tall, sharply rising retinal echo, 4)Medium to tall echoes from the sclera, and 5) Medium to short orbital fat echoes.[1] An acceptable A-Scan would then appear as figure 3. Unacceptable scans are shown in figures 4 and 5.

Within each unit, there is a measuring device to indicate which portion of the scan is being measured. In an A-Scan, this device is called a gate. Some gates are positioned at the baseline of a scan while others are at or near the peaks of the echoes. By positioning the gate in the proper range, we tell the instrument which measurement





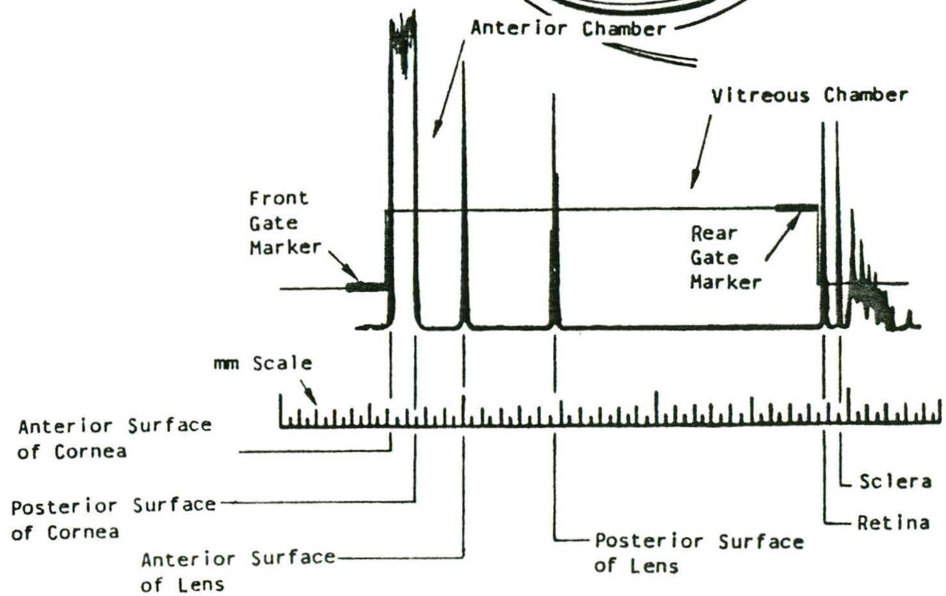


Figure 2
(from Cooper Vision Ultrascan II Operators Manual p.2-14)

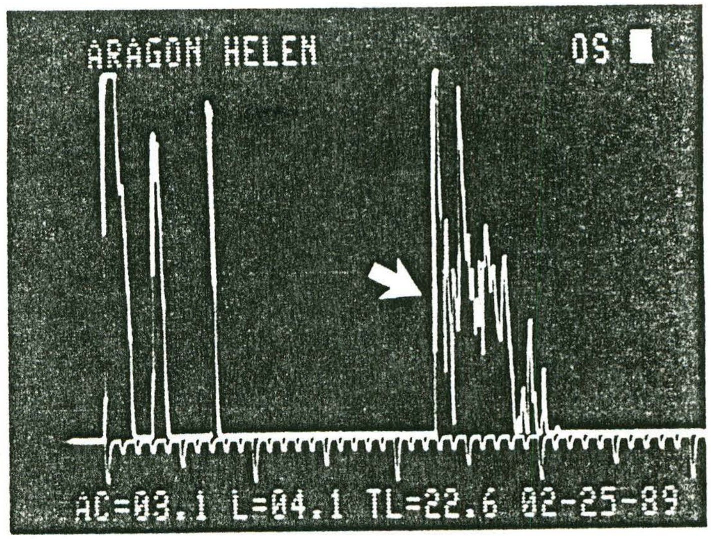


Figure 3 A good retinal echo, tall and sharply rising leading edge.

(from Ophthalmic echography, p.64)

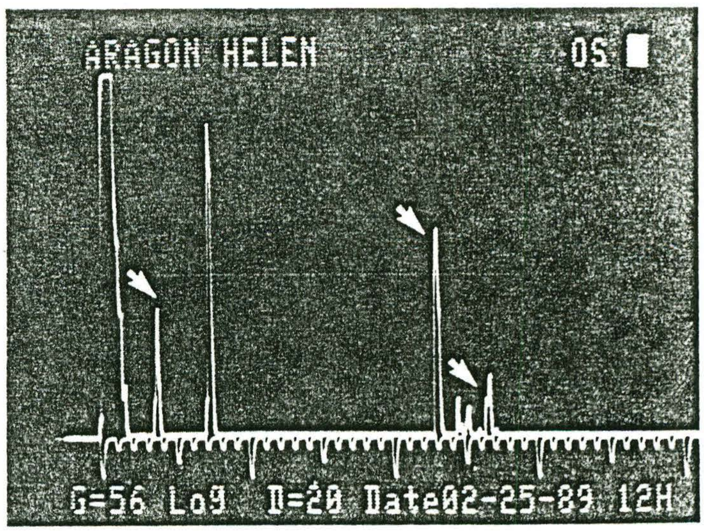


Figure 4 A poor phakic scan shows insufficient anterior lens, retinal, scleral, and orbital fat echoes.

(from Ophthalmic Echography, p.68)

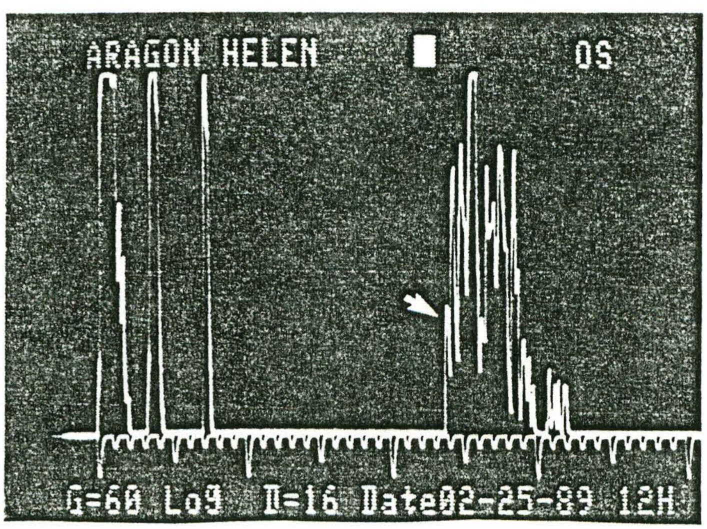


Figure 5 A poor phakic scan has ragged edge of retinal echo, not steeply rising.

(From Ophthalmic echography, p.69)

is desired: axial length, lens thickness, anterior chamber depth, muscle thickness or tumor height.[1] One must be sure the gates are in the proper position to obtain accurate results.[2] If the gates had been moved to compensate for the measurement of a long myopic eye for example, false information will be obtained if the retinal echo doesn't fall within the range of measurement of the gate. An example of improper gate position is figure 6, and proper position in figure 7.

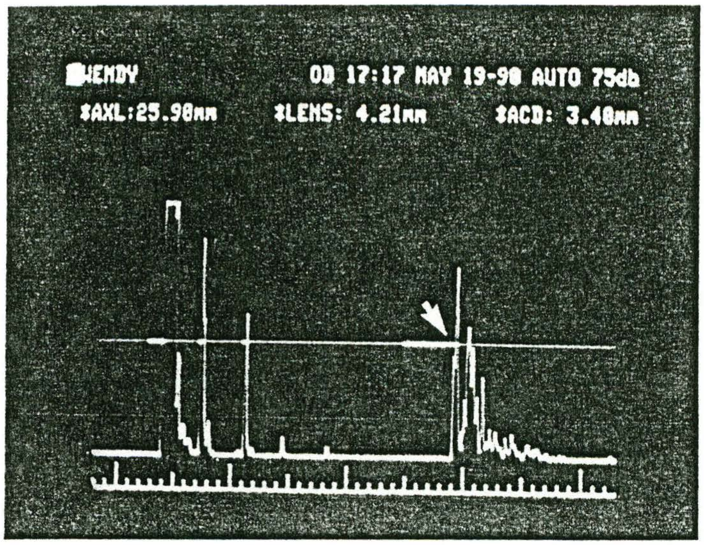


Figure 6 Incorrect retinal gate placement on the higher part of the echo past steeply rising edge shows an increase in measurement of 0.20 mm.

(from Ophthalmic Echography, p.67)

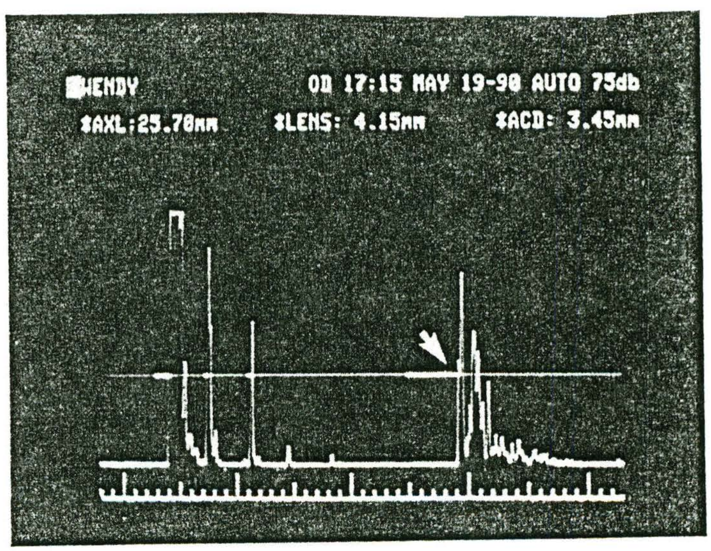


Figure 7 Correct retinal gate placement is on first part of echo's leading or rising edge. Note measurement of 25.70 mm.

(from Ophthalmic Echography, p.66)

Another controllable aspect of the A-Scan is in the gain function. This can be used to produce larger echoes if one is getting a poor echo pattern, for example with a dense cataract that scatters the sound beam more than normal. Again, these controls should be monitored prior to performing an A-Scan and returned to their proper position when finished.

In addition to manually adjusting the gain, there are three factors influencing the height of an A-Scan echo pattern. The first of these factors is the angle in which the sound beam encounters a structure. At angles other than 90 degrees, poorer echoes will be obtained with lower amplitudes , thus making it difficult to interpret the scan.[1] A second factor influencing echo height and brightness is the relative difference between the various tissues that the sound beam encounters. Energy is reflected back to the probe each time a sound beam passes from one tissue to another. Thus, if there is only a slight difference between tissues, smaller echoes will be displayed.[1] The third and final factor affecting the height of the echoes depends on the texture and size of the interface. Smooth surfaces like the retina allow some of the energy to pass through and only reflect portions of it, whereas coarse surfaces tend to scatter the energy and also the appearance of the reflected echoes.[1]

Possible errors in the A-Scan measurement include: performance, problems with the probe, incorrect A-Scan interpretation and problems with amplification. Performance errors can be remedied by actively observing each scan to determine the validity and reliability of individual scans. Another method to monitor performance errors is to perform more than one scan to determine the axial length. One must also be cautious to not indent the cornea during an A-Scan, for this effectively reduces the measured axial length. Probe difficulties usually are the result of too many air bubbles in the fluid filled probes or due to improper probe position. Air bubbles scatter the sound energy transmitted to the eye and thus produce difficult to read scans, while faulty probe position gives improper measurements. Caution should be taken in filling the fluid probes to prevent the formation of bubbles within the probe, as well as positioning the probe (depending on the type of probe and instrument). As previously noted, amplification errors and gate position errors can be monitored by routinely checking their control positions prior to beginning an A-Scan. Finally, the greatest aid in achieving accurate and confident results is by having experience with the particular instrument used and through knowledge of expected scan appearance.

Measurement errors in axial length produce errors in post-operative refraction in a 1mm/3D ratio.[3] Although the axial length is one factor in determining post-operative refraction, it is not as great as one might expect because of the repeatability of the A-Scan measurement. Typical variations that I observed when performing A-Scans were of the .05-.20 range and thus account for less than .50 diopter refractive changes. Other factors are: keratometric data, A-constant values(deal with the final resting position of the IOL expected by the manufacturer and surgeon), actual surgical placement of the IOL, healing, previous refractive error or refractive error of the other eye.

The actual calculation of IOL power is determined by the axial length, average keratometry readings and the value of the A-constant. The A-constant is a number with no units that is used to express the expected relative position that the IOL will finally rest within the eye. These values are usually determined by the manufacturer of the specific IOL and may later be modified by the individual surgeon to conform with his surgical results. Typical expected IOL powers are of the 18-20 diopter range. I did calculate IOL powers for this project, but typically, one may wish to leave this decision to the surgeon because of the factors previously mentioned.

Therefore, the information that needs to be collected to calculate IOL power is the keratometric data and the axial length measurement. To be confident with this data, one must first take a number of readings as well as compare these values to what is expected based on the patient's case history. For example, if I measure a 26.5 mm eye, I then look at the current and past refractive data because normal axial length is typically about 23.5 mm. Also, the data should be correlated with keratometry findings. So, if the above patient had very flat keratometry readings, I would not expect such a high myopic refractive error. On the other hand, if we measure a 21 mm eye with normal K values (about 44 D), we should expect a moderate to high hyperopia. If this does not match the patient's refractive error, we must begin the search for the presumed error in axial length measurement, possibly caused by indenting the cornea during the reading and thus shortening the value that was found. Thus it is very important to work through the expected and actual values to obtain an axial length measurement confidently.

Actual performance of an A-scan would usually begin after the keratometry readings. The eye should be topically anesthetized and the patient seated comfortably in the chair. The probe should be cleansed with either alcohol or hydrogen peroxide to destroy any pathogens and rinsed properly. The probe is then mounted into the tonometer ring if necessary, depending on the type of instrument. There are some hand-held probes which can be ideal for the mobility restricted patient, but these can also be less accurate for measurement. The probe wire should be stabilized to the slit lamp unit either by taping it or by draping it over a fixed object to eliminate possible errors caused by accidental movement of this wire (see figure 2).[4] With the patient comfortably seated and all instrument controls properly positioned, we are ready to perform the measurement. Most units have a fixation light within the probe, so have the patient look directly into this light. Proceed just as in applanation tonometry with extra caution to maintain a steady yet gentle contact with the cornea to avoid compression. Contact time should be limited to only 10 or 15 seconds for individual scans and corneal compression should be carefully monitored. Observe the scan and freeze the individual scans that meet the aforementioned criteria. Some instruments automatically save or freeze a good scan while others have a manual device to perform this task. Perform enough scans until you are confident in your reading.

As noted previously, twenty preoperative evaluations were performed and the data is listed below:

	K readings (180/090)	Axial length	A-constant*	IOL** power
1.	45.25/41.62	22.54	116.6	22.5
2.	45.00/46.00	22.53	116.6	19.5
3.	41.62/41.87	22.94	116.6	22.0
4.	47.75/47.00	22.60	116.6	17.5
5.	46.00/45.00	23.03	116.6	18.0
6.	45.00/46.00	23.53	116.6	17.0
7.	44.75/44.00	22.82	116.6	19.5
8.	45.87/46.00	22.34	116.6	19.5
9.	44.00/45.25	22.50	116.6	20.0
10.	46.00/45.50	23.10	116.6	17.5
11.	41.00/43.00	25.05	116.6	16.0
12.	42.75/44.00	26.07	116.6	12.5
13.	44.12/44.62	23.45	116.6	18.0
14.	44.75/47.00	22.60	116.6	19.0
15.	42.12/41.00	23.95	116.6	19.5
16.	46.00/47.25	22.57	116.6	18.0
17.	44.50/45.50	22.55	116.6	20.0
18.	42.62/42.87	26.10	116.6	13.0
19.	46.00/45.50	23.45	116.6	17.0
20.	42.12/43.00	24.96	116.6	16.0

* A constant used by the surgeon that I performed the A-Scan calculations for.

** IOL power rounded to nearest 1/2 diopter.

The formula used to calculate IOL power was the SRK formula. These calculations do not need to be performed by most Optometrists because of the decisions of desired post-operative refraction, A-constant or other surgical factors. I included these calculations for the completeness of the project and to decide if the expected values match the actual values. Following is the SRK regression formula:

$$P = A - 2.5L - .9K$$

Where:

P= Emmetropia in diopters

A= A constant for the IOL

L= Axial length

K= 2(K1xK2)/K1+K2 (average K readings)

(From Allergan Humphreys owners manual Model 820)

Now that we know these pre-operative workups can be performed with accurate results, I determined the financial benefits that can be gained from doing these procedures. Twenty Optometrists from the MOA Blue Book for Optometry were randomly consulted from the State of Michigan and asked how many cataract surgery referrals were made in an average year. These averages ranged from 5 each year to 100 in a year, thus yielding an average of 3.6 monthly referrals. Once patients are to be referred, one should have a working relationship with a surgeon who will accept the information that you wish to gather. I feel that with the impending Michigan TPA legislation, this type of patient care should be feasible in an Optometric practice. Also, these procedures are currently being done in an Optometric practice here in Michigan.

The next step in calculating the cost effectiveness for this procedure is the determination of the fees to be collected and the typical reimbursements expected from Medicare and Insurance. The Ophthalmology practice that I am employed with bills $220.00 for the A-scan ultrasonography. The CPT code for the procedure is 76519 and their average Medicare reimbursement is $70.00 in the State of Michigan. Another consideration is that in some cases, patients have private insurances that reimburse the full fee for the procedure. The Optometric practice in Michigan previously mentioned has received Medicare reimbursement for the A-Scans that were performed, and the procedure is legal for Optometrists to perform.

A typical A-Scan unit costs approximately $8,000 and this cost has been broken down into 60 monthly payments at a 10% interest rate below. Also, the revenues to the doctor were determined using the minimum expected reimbursement, that for Michigan Medicare of $70, and performing the average 3.6 A-Scans each month.

Costs to Doctor:

$8,000 @ 10% interest over 60 months= $170/month

Revenues to Doctor:

3.6 A-Scans/month @ $70 each= $252/month

Net profit/month:

$252-$170 = + 82.00

Thus for the average practitioner that refers 3 or 4 cataract surgeries each month, this would not be very financially beneficial. Conversely, the Optometrist who expects more that 4 cataract referrals each month would probably do well to include this service in his practice.

In conclusion, A-Scan ultrasonography can be an effective practice builder for the Optometrist seeing significant numbers of cataract patients. Accurate A-Scan results can be achieved consistently with some experience and knowledge about A-Scan and the expected findings. Also, IOL powers are easily calculated although they are not necessary. This service could also be a excellent way to keep the patient informed that their Optometrist is a primary care physician. Finally, the provision of this service to patients expands the primary care services to the patient and is financially beneficial to the Optometrist.

REFERENCES

1. Kendall, C.J., OPHTHALMIC ECHOGRAPHY, Ophthalmic Technical Skills Series, Slack Inc. 1990.

2. Allergan Humphreys Owners Manual Model 820, p.4-12.

3. Kendall, C.J., "Consistent A-Scan technique leads to reliable IOL choice", OCULAR SURGERY NEWS, 1991;9:28,29.

4. Cooper Vision Ultrascan II Operator Manual, p.2-9.