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Clinical experience with automatic midline echoencephalography: cooperative study of three neurosurgical clinics[1]

M. KLINGER, E. KAZNER,[2] TH. GRUMME, V. AMTENBRINK, G. GRAEF, K. H. HARTMANN, H. HOPMAN, W. MEESE, AND B. VOGEL

From the Neurosurgical University Clinics, Berlin, Erlangen, and München, GFR

SYNOPSIS Computerized midline echoencephalography was developed in order to make the determination of the midline more objective. In a group study involving the neurosurgical clinics in Berlin, Erlangen, and Munich, a total of 1 889 patients with various intracranial diseases was examined by this method. An exact analysis of the results obtained is presented: 18% were unsatisfactory.

A-scan echoencephalography has become widely used in recent years and is now an indispensable tool in the diagnosis of intracranial lesions (Grossman, 1966; Pia and Geletneky, 1968; Schiefer *et al.*, 1968). However, the literature contains many reports on the difficulties this method presents, especially for the beginner (McKinney, 1964; Jefferson and Hill, 1966, 1968; Kramer, 1968; White, 1967, 1970, 1972; White and Hanna, 1974). Experienced investigators have emphasized for years that prolonged practice is necessary before echoencephalography can yield truly reliable and accurate results. Comparing the error rates of various authors, it becomes evident that the percentage of mistakes is considerably higher in smaller series than when the number of examinations exceeds 300 patients (Schiefer *et al.*, 1968). An error quota of over 10% in some series rapidly led to disappointment and to a discreditation of A-scan echoencephalography. Since some authors of large series were able to achieve an accuracy as high as 99%, special emphasis was placed on the condition that echoencephalography should be performed only by physicians with adequate training. Naturally this would limit the number of investigators considerably. White (1972), on the other hand, goes so far as to say that he does not consider such a test to be of clinical value if it depends upon the presence of a neurological specialist.

METHOD

In an effort to eliminate as much as possible the factor 'experience' in the determination of the midline echo and to provide scientific objectivity, there has been no lack of attempts to standardize this examination, especially on the North American continent. White and his research group were particularly active in searching for an automation of this diagnostic procedure which would exclude the subjective influence of the examiner so that paramedical personnel could quickly learn to handle the equipment.

In the search for suitable apparatus, Galicich and Williams (1971) attempted to achieve the following goals:

1. Substitution of criteria for automatic pattern recognition for the decision of the operator.
2. Concentration of the attention of the operator to applying the detector probe to the patient's head.
3. Acquisition and recording of enough single-orientation values to establish statistical confidence in the echo pattern detected.

In 1971 Galicich and Williams presented the automatic midline computer, known as the Midliner, that seemed to fulfill these conditions (Fig. 1). The

[1] Presented at the 2nd DAUD-meeting in Hanover, 18 May 1974.
[2] Address for correspondence: Priv. Doz. Dr E. Kazner, Neurochirurgische Klinik im Klinikum Grosshadern der Ludwig-Maximilians-Universität, D-8000 München 70, G.F.R.
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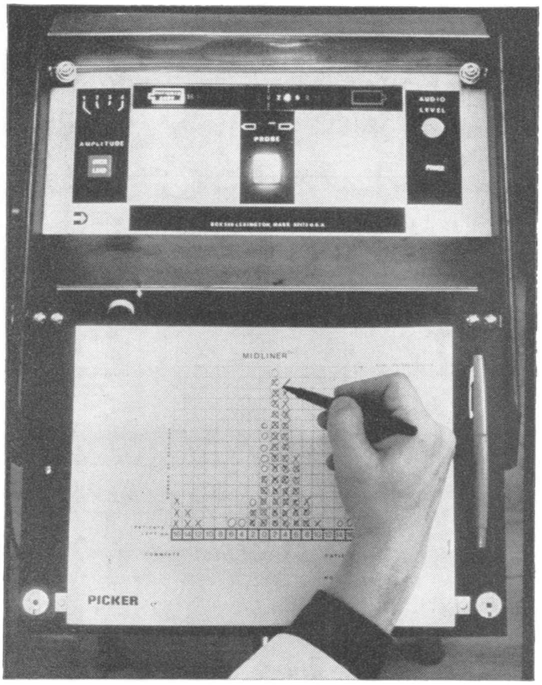

FIG. 1 *Investigation with the Midliner. Note lack of oscilloscope. Readings appear on digital scale.*

principle of operation is explained in Fig. 2. A 2 MHz transducer with a pulse repetition rate of 500 cycles is applied in the hair-free zone above the ear. The computer first searches for the double end echo, one echo coming from the inner table of the skull and the other from the skin-air interface. Upon finding the distal echo, the computer measures the diameter of the skull and automatically determines the theoretical midline by dividing the distance from probe to distal echo in half. Now the mid-gate is opened to search for the midline echo. The gate area is limited to 32 mm—that is, 16 mm to the right and to the left of the theoretical midline, thus comprising about 20% of the total distance. If the computer finds a single high echo here, the position of this echo is shown as a lit-up number on the digital scale. Simultaneously a 500 Hz tone is heard. If the computer fails to find a single high echo in the gate area or registers several high echoes, the digital scale remains dark and the computer begins anew with the determination of the digital echo.

When a successful measurement has been made the number appears on the digital scale and this number is recorded on a special data sheet with different symbols for the right and the left side. Subsequently a new cycle is initiated by pressing on the reset button. The examination from one side is completed if one column is filled. Galicich and Williams (1971) called the completed data sheet a histogram to distinguish it from the echoencephalogram or echogram. The duration of the Midliner examination depends on the number of measure-

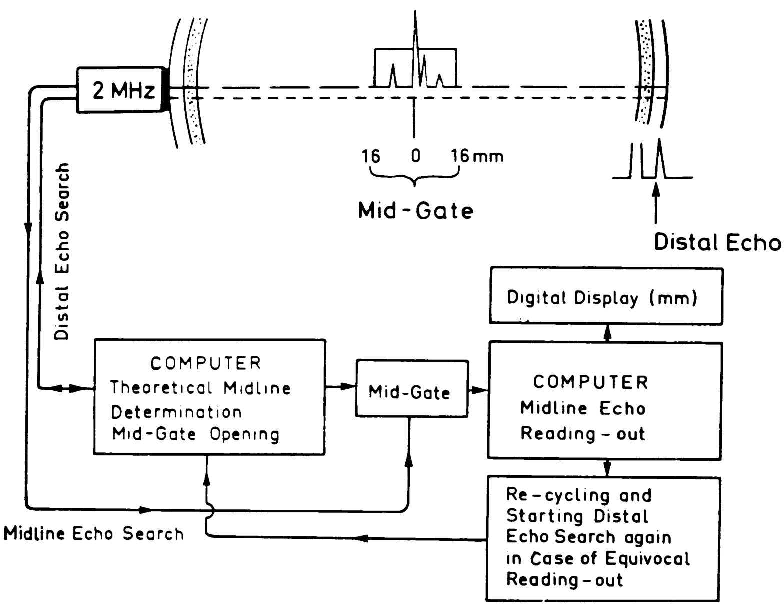

FIG. 2 *Principle of computerized midline echo encephalography (after Galicich and Williams, 1971).*

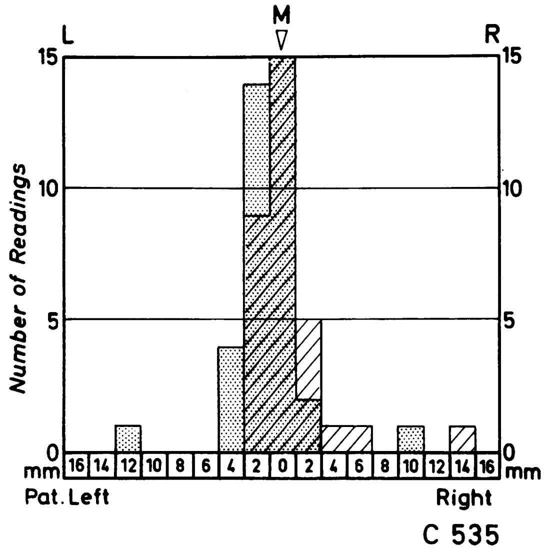

FIG. 3 *Normal histogram showing a block of readings in the midline.*

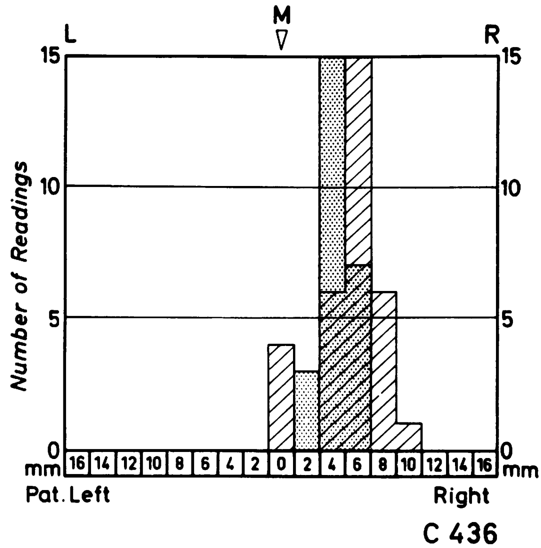

FIG. 4 *Pathological histogram showing a distinct midline displacement from left to right in the presence of a tumour in the left temporal lobe.*

ments necessary before either a satisfactory or an unsatisfactory histogram has been obtained. This may take from five to as much as 40 minutes in difficult cases. The time can be reduced considerably to about three minutes if two persons carry out the examination together: one person handles the probe while the other concentrates on the Midliner and writes down the digits as they appear on the scale. Since a large number of measurements is made, the midline echo possesses statistical significance. Figure 3 shows a normal histogram of a patient without a shift of the midline structures. In contrast, the histogram in Fig. 4 demonstrates a distinct shift of the midline structures from left to right in a patient with a left temporal tumour. This finding stood in perfect correlation with the displacement in the A-scan echoencephalogram and with the position of the internal cerebral vein in the carotid angiogram.

In order to investigate whether the Midliner really fulfils the requirements mentioned above, a cooperative study of the neurosurgical departments of three different hospitals was carried out. Special attention was directed to the use of the Midliner in cases of head injuries suspected of having intracranial haematomas. A completely accurate determination of the midline that could be carried out by every physician in a small hospital or by paramedical personnel would have the enormous advantage of preventing the unnecessary transport of the patient over long distances. Even without the various possibilities of echoencephalography, such as the measurement of ventricular width, the observation of tumour echo complexes or the detection of a haematoma echo, the absolutely certain determination of the midline echo would justify the use of such an automated method.

RESULTS

Altogether 1 889 patients underwent the midliner investigation. Table 1 presents a survey of the diagnoses of these patients: there were 591 brain tumours, 312 head injuries, nearly 200 cases of cerebrovascular disease, and 414 patients with various intracranial diseases. Only 374 subjects were unremarkable at clinical and echoencephalographic examination and

TABLE 1

DIAGNOSES OF 1 889 PATIENTS INVESTIGATED WITH AUTOMATIC MIDLINE COMPUTER

	Number of patients investigated in			
Diagnosis	*Berlin*	*Erlangen*	*München*	*Total*
Brain tumour	127	183	281	591
Head injury	115	73	124	312
Cerebrovascular lesion	43	37	118	198
Intracranial disease of other aetiology	95	20	299	414
Normal	249	117	8	374
Total	629	430	830	1 889

TABLE 2

RESULTS OF AUTOMATIC MIDLINE DETERMINATION IN 1 889 PATIENTS IN COMPARISON WITH A-SCAN ECHOENCEPHALOGRAPHY

Histogram	*Number of cases* Berlin	Erlangen	München	Total	*Comparison with A-scan* Correct	Incorrect
Normal	322	277	512	1 111	1 100 = 99%	11 = 1%
Midline shift	118	102	214	434	401 = 92%	33 = 8%
Unsatisfactory	189 (30%)	51 (12%)	104 (13%)	344 (18%)		
Total	629	430	830	1 889	1 501 = 80%	44 = 2.3%

TABLE 3

SURVEY OF UNSATISFACTORY AND INCORRECT HISTOGRAMS IN 388 CASES

Histogram	*Number of cases* Berlin	Erlangen	München	Total
False positive ('shifted' in Midliner although midline normal)	15	8	10	33
False negative (normal in Midliner although midline shifted)	4	3	4	11
Technically inadequate (widely scattered measurements, no unequivocal midline)	145	14	48	207
No response obtainable (thickness of skull, age)	44	18	37	137
Response from one side only (trauma or swelling opposite side)		19	19	
Total	208	62	118	388

TABLE 4

RESULTS OF AUTOMATIC MIDLINE MEASUREMENT IN 249 NORMAL CONTROLS OF VARIOUS AGE GROUPS (NEUROSURGICAL UNIVERSITY CLINIC, BERLIN)

Age group (a)	*Number of cases*	*Histogram* Normal (Correct)	Shift (Incorrect)	Unsatisfactory (no.)	(%)
Children up to 1	55	14	1	40	72
From 2 to 16	74	49	0	25	34
Adults					
From 16 to 60	61	57	1	3	5
Over 60	59	38	0	21	36
Total	249	158	2	89	36

these serve as the control group. Since the accuracy of the diagnosis is particularly important in these patients, all findings were compared with an A-scan echoencephalogram carried out by an experienced physician. Wherever possible, the neuroradiological findings were also compared with the histogram (see Table 7).

In order to prevent operator bias, many of the Midliner measurements were carried out by untrained students. Table 2 shows a comparison between these Midliner histograms and the A-scan echograms performed by a trained operator. In 1 889 cases, the histograms were found to be normal 1 111 times. In 1 100 cases this was confirmed, so that the accuracy for the normal midline echo was 99%. Of the 434 cases of Midliner displacement, 401 (92%) were confirmed and thus correct and 33 (8%) were incorrect. Taking the group of unsatisfactory results into consideration, which comprises no less than 18%, the overall accuracy of the midline computer measurements was only 80%. The high percentage of unsatisfactory histograms in the Berlin series is due to their particular age distribution, which is explained in detail below. The fact that rigid standards were applied to the interpretation of the histograms is a further reason for the large number of noninterpretable measurements. Special attention was given to two criteria: (1) the measurement must be recordable from both sides of the skull; (2) these values must form a single block which can be clearly identified as the midline echo.

Table 3 gives a survey of the 388 unsatisfactory and incorrect measurements. In 44 patients, the results of the two methods of examination (Midliner and A-scan) did not agree. The Midliner showed a displacement which could not be veri-

TABLE 5

COMPARISON OF AUTOMATIC MIDLINE DETERMINATION AND A-SCAN ECHOENCEPHALOGRAPHY IN 196 PATIENTS WITH VARIOUS INTRACRANIAL LESIONS (NEUROSURGICAL UNIVERSITY CLINIC, ERLANGEN)

Diagnosis	*Number of cases*	*Midliner*			*A-scan*		*Agreement*	
		Normal	*Shift*	*Unsatisfactory*	*Normal*	*Shift*	*(no.)*	*(%)*
Brain tumour	132	49	57	26	62	70	98	74.2
Head injury	41	13	15	13	17	24	28	68.3
Cerebrovascular lesion	23	13	7	3	15	8	20	87
Total	196	75	79	42	94	102	146	74.5

TABLE 6

SURVEY OF UNSATISFACTORY AND INCORRECT HISTOGRAMS IN TWO SUBSEQUENT SERIES (NEUROSURGICAL UNIVERSITY CLINIC, ERLANGEN)

Histogram	*First series 150 cases*	*Second series 150 cases*
False positive ('Shifted' in Midliner although midline normal)	6	1
False negative (Normal in Midliner although midline shifted)	3	1
Technically inadequate (Widely scattered measurements, no unequivocal midline)	10	2
No response obtainable (Thickness of skull, age)	11	5
Response from one side only	13	3
Total no.	43	12
Per cent	29	8

fied in 33 cases—that is, a false positive result. Considerably more dangerous is a false negative finding in which the midline appears to be normal in the histogram while the cerebral midline is actually displaced. However, the percentage of such errors in the total of 1 889 patients was only 0.6%. Technical difficulties were met in 207 cases: most of these had histograms containing many scattered values without an unequivocal midline echo block. Since increased scatter is more likely to occur in patients with intracranial disease than in healthy subjects, the failure to obtain a single midline column must be regarded as an indication for further diagnostic investigations, an observation made by White (1972) as well. Whenever the consistency of the skull changes—for example, increased thickness of the bony skull or pneumatization of the bone—the Midliner was unable to record a value because the ultrasound beam is absorbed too strongly. As Table 4 shows, this is particularly true for patients over the age of 60. The dependence on the age of the patient is impressively demonstrated in this series in which the high percentage of non-recordable measurements in infants is surprising. This is due to the setting of the Midliner scale which is limited to a head diameter of 13 to 18 cm. This age distribution is responsible for the high per-

TABLE 7

COMPARISON OF MIDLINER RESULTS AND NEURORADIOLOGICAL FINDINGS IN 585 PATIENTS (COMPARED WITH SERIES OF 573 CASES FROM WHITE AND HANNA, 1974)

Histogram	*Klinger et al. (1975)*			*White and Hanna (1974)*		
	No. of cases	*Agreement with neuroradiol.*	*No agreement with neuroradiol.*	*No. of cases*	*Agreement with neuroradiol.*	*No agreement with neuroradiol.*
Normal midline	233	225	8	474	468	6
Midline shift	352	341	11 (3.2%)	99	83	16 (16%)
Total	585	566	19	573	551	22
Per cent	100	96.7	3.3	100	96.2	3.8

centage of unsatisfactory histograms in the Berlin series (Table 2). A large proportion of the unsatisfactory measurements was due to the fact that the echo could be recorded only from one side or not at all (Table 4). Since a subgaleal haematoma generally prevents the detection of an unequivocal M-echo, a considerable number of patients with head injuries could not be examined. For this reason, the agreement between histogram and A-scan echoencephalogram was rather poor in this group: only 68% of the measurements in cases of head injuries were in agreement (Table 5). Because of the large number of unsatisfactory Midliner measurements, only 79 of 102 midline shifts could be detected using the Midliner (77%).

Although one would assume that the Midliner read-out is entirely objective and independent of the experience of the examiner, Table 6 contradicts this assumption. This Table shows two succeeding series of 150 cases, each performed by the same untrained student. It is obvious that the Midliner examination must be learned just like other methods. The total error rate sank from 29% in the first series of 150 cases to 8% in the subsequent group—the difference is doubtless due to experience with the Midliner technique.

DISCUSSION

Comparing these results with those in the literature shows apparently better overall results by other authors. Thus, in a series of 3 333 cases, White and Hanna (1974) observed only 3% unsatisfactory results. An exact analysis of their results reveals that these were mainly normal findings (89.7%). The accuracy in 2 089 cases of normal histograms was 98.9%. The comparable degree of accuracy in the series presented here is also 99%. Turning to the histographic shifts, the error rate of 16% reported by White and Hanna is significantly higher than the corresponding 8% rate in our study. To make the figures truly comparable, the Midliner measurements were compared with the neuroradiological findings in both series. The results (Table 7) indicate that the difference in the percentage of incorrect values is even more significant: 16% of the measurements in the Kingston series failed to concur with the neuroradiological finding, while only 3.2% of the measurements in our group study could not be confirmed by radiological methods. Despite the good agreement shown in Table 7, the high number of unsatisfactory results is a severe drawback.

In view of the fact that the rate of unsatisfactory results ranges from 13 to 32% depending on the type of intracranial pathology (Table 5), the automatic midline computer cannot replace conventional A-scan echoencephalography, even if only the determination of the cerebral midline is considered. Therefore the Midliner can only be regarded as a first step on the way to automatic midline determination.

In some unclear cases, the use of the Midliner in addition to the A-scan echoencephalograph can provide further information so that its use as a second apparatus in a neurological or neurosurgical clinic is feasible. However, the large number of unsatisfactory measurements makes it of limited use for practising neurologists and emergency departments of small hospitals. As experience in all three hospitals involved in this study has shown, the computerized determination of the midline echo is not reliable enough to warrant its use in cases of head injury.

New techniques for the determination of the cerebral midline using ultrasound are currently being developed. The results of Hudson and Müller (1974) with a compact echoencephalograph appear promising and remain to be tested by other investigators.

SUMMARY

The examination of the brain with ultrasound has become a routine method of neurological diagnosis. Although A-scan echoencephalography has provided very good results, the need for a more objective method of determining the cerebral midline prompted the development of the automatic midline computer. The Midliner which makes fewer demands on the experience of the investigator than conventional A-scan echoencephalography, was studied in a combined study in the neurosurgical clinics in Berlin, Erlangen, and Munich. A total of 1 889 patients with various kinds of intracranial pathology underwent investigation. As the results showed, the accuracy of the Midliner is

good in cases of unshifted midline—1 100 measurements of the 1 111 cases could be confirmed, which is an accuracy of 99%. However, the Midliner hardly lives up to expectations, since no less than 18%—that is almost one-fifth of the values—were unsatisfactory.

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