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EPIDEMIOLOGY STUDIES SCREENING FOR THE EARLY DETECTION OF DISEASE IN INDIVIDUALS EXPOSED TO VINYL CHLORIDE

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SCREENING FOR THE EARLY DETECTION OF DISEASE IN INDIVIDUALS EXPOSED TO VINYL CHLORIDE

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ABSTRACT

A prospective collaborative study was conducted to compare the effectiveness of four clinical techniques in the detection of liver damage due to vinyl chloride monomer exposure. A chemically exposed and medically monitored worker population was identified by histopathological and biochemical documentation. Three techniques were non-invasive: a) grey scale ultrasonography of the liver, b) microvascular skin capillary assessment, and c) urinary analysis of glycosaminoglycan excretion. The fourth technique was the standard ^{99}mTc sulfur colloid radionucleotide liver spleen scan. The screening studies were performed on a randomly selected single cohort of chemical workers; some of whom were known to have disease. All four techniques were analyzed for their sensitivity and specificity as compared to results of the liver biopsy and biochemical blood test classification. Although all four screening techniques had a sensitivity and specificity sum greater than one, none were significantly better than could be explained by chance or the use of a biased coin. Reclassification of the population into those with more severe biochemical abnormalities improved the sensitivity of all screening tests, but only the sensitivity and specificity sum for the GAG test were statistically significant at the 0.05 level. There was no significant correlation between any pair of screening tests. None of the four screening tests agreed with the biopsy results better than might be obtained by biased coin or chance. These screening studies as presently constituted, do not provide sufficient sensitivity and specificity to warrant their use in community screening for subclinical asymptomatic hepatic injury due to chemical exposure.

INTRODUCTION

The initial reports of primary liver cancers (angiosarcoma) in rats exposed to vinyl chloride by Maltoni, et al (1) and the discovery of similar liver tumors in vinyl chloride polymerization workers by Johnson and Creech (2) has lead to considerable environmental concern regarding communities surrounding chemical industries which utilize potentially carcinogenic agents such as vinyl chloride. Several investigators have reported on various screening techniques as effective indicators of vinyl chloride chemical injury. Four such techniques - ultrasonography (3), radionucleotide scanning (4), nailbed capillary visualization (5), and glycosaminoglycan (GAG) (6) excretion - were reported to have some possible usefulness in detecting early chemical injury to the liver. In order to determine the useability of these techniques for community screening, the American Public Health Association (APHA) and Environmental Protection Agency (EPA) funded a multi-center collaborative study designed to determine the comparative sensitivity and specificity of these various techniques in detecting and identifying chemical related hepatic injury in asymptomatic individuals.

Materials and Methods

Population Selection

The chemical worker population consisted of 1,178 active (Group B, Figure 1) employees as of September 1, 1977, and 70 employees who had had liver biopsies regardless of current employment status (Group A, Figure 1); they were undergoing annual medical screening for the identification of work-related disorders. The medical screening consisted of an annual or semi-annual (for those employees with 10 or more years of employment) comprehensive history and physical examinations, laboratory screening studies consisting of 35 biochemical tests, chest and abdominal X-rays, and radionucleotide liver-spleen scan.

This population was selected for the collaborative study to determine the comparative effectiveness of four screening techniques in detecting liver damage as indicated by 1) past histopathological documentation of liver injury of 2) current hepatic dysfunction identified biochemically.

Three of the four techniques were included as potential non-invasive procedures suitable for determining the effects of vinyl chloride in a community population. These included 1) grey scale ultrasonography of the liver as developed by Taylor and colleagues (7, 13, 14), 2) a nailbed skin capillary evaluation of the middle and distal phalanges of the fingers as developed by Maricq and associates (8), and 3) urinary analysis of glycosaminoglycan excretions (GAG) as published by Kupchella and associates (9).

The fourth method included for comparison purposes was the standard radionucleotide liver-spleen scan utilizying ^{99}mTc colloid and interpreted by Whelan and associates (10).

The non-invasive screening studies were performed during a single week on a group randomly selected from all chemical company employees. The workers were selected on the basis of complete medical and work data for 1976-1977, and all those employees who had investigative liver biopsies performed during the screening program (1974-1977). The selection process for these workers is illustrated in Figure 1. The biochemical data and radioisotopic scans were part of the routine medical surveillance system for the employees. The pathological data was based on the last or most recent liver biopsy (s) which were performed for medical reasons, both related and not related to their work. Positive and negative results were determined as defined in Table 1 which list the technique, the evaluation or evaluators, and the criteria used. The employees targeted for examination were selected by simple random sampling from all available employees.

One hundred and twenty one of the targeted 170 employees (71 percent) participated. Twenty six declined to participate or could not be scheduled; 13 did not keep their scheduled appointment. After participation, nine employees were discovered to have been misclassified as biochemically abnormal. They had some biochemical abnormalities but not all (classified intermediate) and have been eliminated from the final analysis. Four biochemically abnormal individuals had abnormally low test values and they were included in the analysis.

Liver Biopsies

Liver biopsies were performed by the transjugular technique (11) and provided two to five biopsies from various areas of the liver. In addition, some individuals had second biopsies performed by the percutaneous or wedge biopsy via mini-laparotomy procedures. Pathological data was recorded in a computerized format identifying all histological abnormalities in a semi-quantitative fashion. Biopsies were read without knowledge of the individual's medical history or chemical exposure by two pathologists and a hepatologist with extensive experience in hepatic chemical injury. All biopsies were classified as 1) normal, 2) abnormal, a) chemical injury, and b) non-chemical injury.

The non-biopsy groups were drawn from those currently employed, and based on biochemical liver "function tests" individuals were sorted into positive, negative and indeterminate for hepatic disease. Only the positive and negative are included in this study.

The ultrasonic evaluation and its relative ability to identify hepatic damage due to vinyl chloride has been published elsewhere (3).

Microvascular techniques and the method of evaluation by Dr. Maricq and co-workers are also published in part (8).

The experimental work on GAG excretion in vinyl chloride workers and the techniques for differentiating the electrophoretic patterns in patients with

angiosarcoma and connective tissue damage of the liver has been published elsewhere (9). The effectiveness of radioisotopic (radionucleotide) scanning as a technique for identifying anatomical lesions in vinyl chloride workers is in preparation (12).

Method of Analysis

The biopsied group and the non-biopsied (biochemical) group were analyzed independently. For the biopsied group sensitivity and specificity were estimated for each screening test by assuming that the biopsy was correct. For the biochemical group the biochemical classification was assumed to be correct. For each analysis the data consisted of a simple cross classification. In a perfect screening test, the sum of sensitivity and specificity would be two. In a screening test which provided results no better than could be obtained by using a biased coin, the sum of sensitivity and specificity would be equal to one. We, therefore, estimated 95% confidence limits for the sum of sensitivity and specificity and observed whether or not one is included within these limits. As a test of statistical significance this is equivalent to the usual X^2 test for independent proportions.

Finally, in Table 4 we looked at the association (as measured by the phi coefficient) between each pair of screening tests. For these comparisons we used all employees who received both screening tests regardless of their biopsy status. In this case, we assumed both tests were subject to error and estimated the phi coefficient (r_ϕ) between them. Finally, for completeness, we give the biochemical classification for the 51 employees included in the biopsy group.

Results

Table 2 compares the histological and biochemical results for the 51 biopsied employees included in the study. Twenty-two of these employees had biochemical abnormalities as defined in Table 1. There was no significant

correlation between the biochemical and biopsy classification for the 29 employees with positive or negative biochemical classifications ($r_\phi = 0.21$; $X^2_1 = 0.20$). The biochemical studies used in this analysis were those determined at the time of this and not at the time the biopsy was performed. In all instances of disagreement, the biopsy was positive and the biochemical results negative ($P < 0.001$).

Figure 2 provides the sensitivity and specificity for each of the screening tests when compared to biopsy results. In no case is the sum significantly greater than one, indicating that the results are not statistically significantly better than could be obtained using the biased coin. With the exception of the GAG studies, similar results are obtained when comparing the sum of sensitivity and specificity in the biochemical group (Figure 3). The sum of sensitivity and specificity for the GAG studies are just statistically significant with 95 percent confidence limits of 1.06 to 1.52. Table 3 gives the frequency distribution of the results of the GAG test for employees with normal and abnormal biochemical results. The distributions differ in their spread (variance) and not in their location (means).

Finally, the correlation matrix for the four tests are given in Table 4. There is no significant correlation, as measured by r_ϕ, between any pair of the screening tests. This is also true when they are sorted by biopsy status.

After reviewing the results, a reclassification of the 51 employees who had biopsies was assessed in regard to whether there was chemically induced liver damage. Ultrasonographic evaluation was reclassified by Dr. Taylor and the liver biopsies by Drs. Tamburro and Popper. Table 5 gives the results of this additional analysis which demonstrates that there was no agreement that could not be explained by chance ($P = 0.60$).

Discussion

The increasing industrialization in highly developed Western countries, such as the United States, continues to provide concern, not only for the health and safety of the industrial workers, but also for the surrounding communities in the areas of these industries. It is highly desirable to identify and validate the reliability of screening and diagnostic techniques which will identify the early development of injury due to the exposure of a variety of chemicals such as vinyl chloride. The assessment of newly developing techniques on a high-risk, exposed worker population, who have been carefully screened and prospectively followed, provide the most reliable method for determing both the sensitivity and specificity of these technical procedures in the asymptomatic subclinical high-risk exposed community population. The failure of such techniques to provide sufficient sensitivity in the presence of a required specificity is of critical clinical importance. This is especially so where the incidence of disease is relatively low and the population exposed large. Tests which provide a high sensitivity but of low specificity can and do medically stigmatize the population under surveillance leading to unnecessary anxiety and socioeconomic disturbances which can far outweigh the benefit of early detection of even serious disease in a smaller population.

Far too often screening techniques which have been developed in a highly diseased, clinically overt, hospitalized population are applied to an asymptomatic, clinically well-working populations without adequate determination of the sensitivity and specificity at this earlier stage of disease development.

In this study, all four techniques had, in the highly diseased hospitalized population, demonstrated either a sensitivity or specificity suggestive for the identification of underlying chemically related liver disease. Some techniques (Maricq and Kupchella) appeared ideal for community studies since they were non-invasive, relatively inexpensive, and provided a means of screening which would be highly accepted by a community.

This prospectively designed study has allowed us to estimate the ability of ultrasonography, nailbed capillary assessments, radioisotopic scanning, and glycosaminoglycan excretions to correctly predict the presence and absence of hepatic disease as documented by an exposed population. These studies clearly show that none of the four screening techniques sufficiently agree with either the biopsy, the biochemical results, or each other in a well defined population; they do not provide sufficient sensitivity or specificity to be useful as early indicators of chemical exposure injury.

The inclusion of nine individuals with intermediate biochemical results, who were originally misclassified as abnormal, would decrease the sum of sensitivity and specificity in all three screening tests. With their exclusion only the GAG tests provided results better than might be expected by chance ($P < 0.05$). Even the GAGs, from a pragmatic point of view, provide too high a false positive rate to be useful in its present stage. Possibly, with increased refinement and further study, this might provide a simple non-invasive technique for the identification of increased collagen changes related to chemical injury. More immediately, it should be duplicated to rule out chance.

Had we eliminated the four employees with an abnormally low biochemical test values, the sum of sensitivity and specificity for the GAGs and nailbed skin capillary screening tests would have been slightly reduced and that for the scan slightly increased. The GAG would still be of bordering significant ($X^2_1 = 3.73$), and the scan not significant ($X^2_1 = 1.46$).

Finally, the tests not only disagree with each other, but within the biopsy group there was no agreement between the biopsies and biochemical results. It should be noted, however, that the biochemical studies used in analysis were those chronologically closest to September, 1977, and not to the date of biopsy.

The test determinations and the biopsies may have been as long as three years apart. An analysis of the biochemical tests value done at the time of the biopsy would have more accurrately reflected the liver status, as shown by histology (15). It has been shown, in previously published studies, that biochemical and histological findings each correlate with chemical injury and chemical exposure (16, 17).

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Table 1

CLASSIFICATION	DETERMINED BY	CRITERIA
Biopsy	1) Dr. Popper, Pathologist 2) Dr. Makk, Pathologist 3) Dr. Tamburro, Hepatologist	a) Positive by consensus agreement if medically significant pathology is present. Negative otherwise. b) Pathology is of chemical or non-chemical origin. (18)
Biochemical	Liver "Function" Tests Group 1: SGPT, ICG, SGOT, ALK. PHOSPHATASE Group 2: GGTP, BILIRUBIN	Positive if two or more Group tests were abnormal or if one Group 1 and both Group 2 tests were abnormal. Negative if all six tests were normal. Intermediate otherwise.
Ultrasound	Dr. Taylor	Defined as negative if the overall impression was normal. Positive otherwise.
Microvascular	Dr. Maricq	Defined as negative if there were no microvascular abnormalities. Positive otherwise.
Glycosaminoglycans	$\text{Uronic acid} = \frac{\text{UG Uronic Acid}}{\text{MG Creatinine}}$	Defined as positive for values less than 2.0 or greater than 4.8. Negative otherwise.
Liver Scan	Dr. Whelan	Defined as positive if any pathological defect was detected. Negative Otherwise.

TABLE 2

COMPARISON OF BIOPSY AND BIOCHEMICAL DETERMINATIONS OF THE PRESENCE OF LIVER DISEASE

BIOPSY	BIOCHEMICAL		SUM	BIOCHEMICALLY INDETERMINATE	TOTAL
	POSITIVE	NEGATIVE			
POSITIVE	3	18	21	15	36
NEGATIVE	0	8	8	7	15
SUM	3	26	29	22	51

$r = 0.20966$ $\quad X_1^2 = 0.200$ N.S.

Matched $X_1^2 = (18 - 1)^2/18 = 16.1$ $\quad P < 0.001$

TABLE 3

FREQUENCY (F) AND RELATIVE FREQUENCY (R.F.)
OF GAGS FOR NORMAL AND ABNORMAL
BIOCHEMICAL RESULTS

GAG	Normal		Abnormal	
	f	R.F.	f	R.F.
< 2	4	0.111	6	0.250
2 < 3	16	0.444	7	0.292
3 < 4	13	0.361	6	0.250
4 < 5	1	0.028	1	0.042
5+	2	0.056	4	0.167
Sum	36	1.000	24	1.000
Mean	2.886		3.160	
Variance	0.746		1.776	

$t_{58} = 0.968$ N.S. T Test Independent Means

$F_{23,35} = 2.381$ $P < 0.05$ F Test Independent Variances (Two Tailed)

TABLE 4

CORRELATION MATRIX (Ro) BETWEEN FOUR SCREENING TESTS USED TO PREDICT THE PRESENCE OR ABSENCE OF LIVER DISEASE

	GAG ANALYSIS	CAPILLARY ASSESSMENT	ULTRASOUND STUDY	RADIOISOTOPIC SCAN
GAG ANALYSIS	.	0.08	-0.03	0.005
CAPILLARY ASSESSMENT	(113)	.	0.03	0.07
ULTRASOUND STUDY	(87)	(84)	.	0.06
RADIOISOTOPIC SCAN	(120)	(114)	(88)	.

None of the correlations are statistically significant (a = 0.05).
The correlations are given above the diagonal.
The sample size is given in parenthesis below the diagonal.

TABLE 5

RECLASSIFICATION OF BIOPSIED EMPLOYEES

FOR CHEMICALLY INDUCED ABNORMALITIES

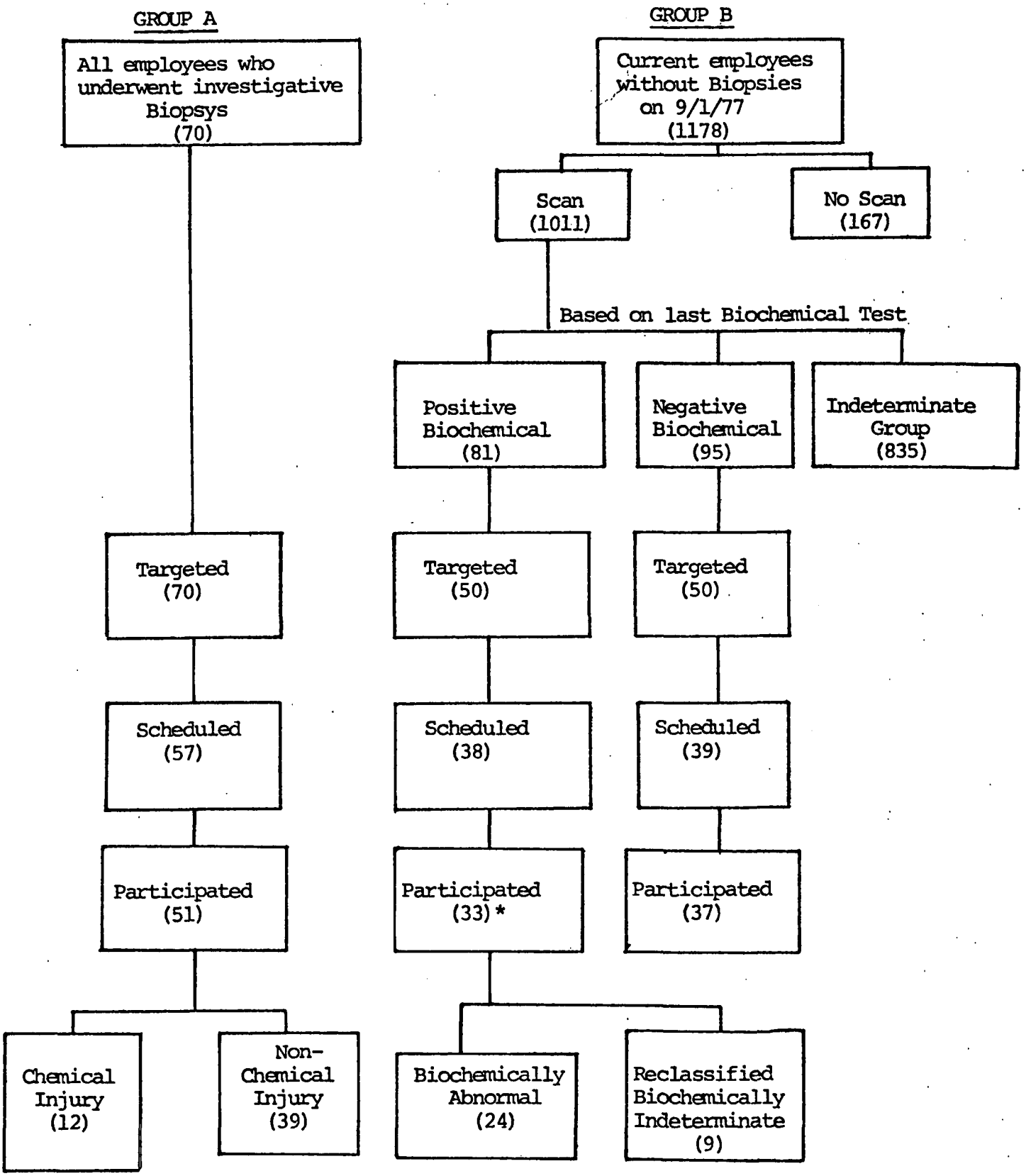
Biopsy	Ultra Sound		SUM
	Chemical Abnormality	Other	
Chemical Abnormality	7	5	12
Other	26	13	39
SUM	33	18	51

Specificity = 13/39 = 0.333

Sensitivity = 7/12 = 0.583

Sum = 0.916

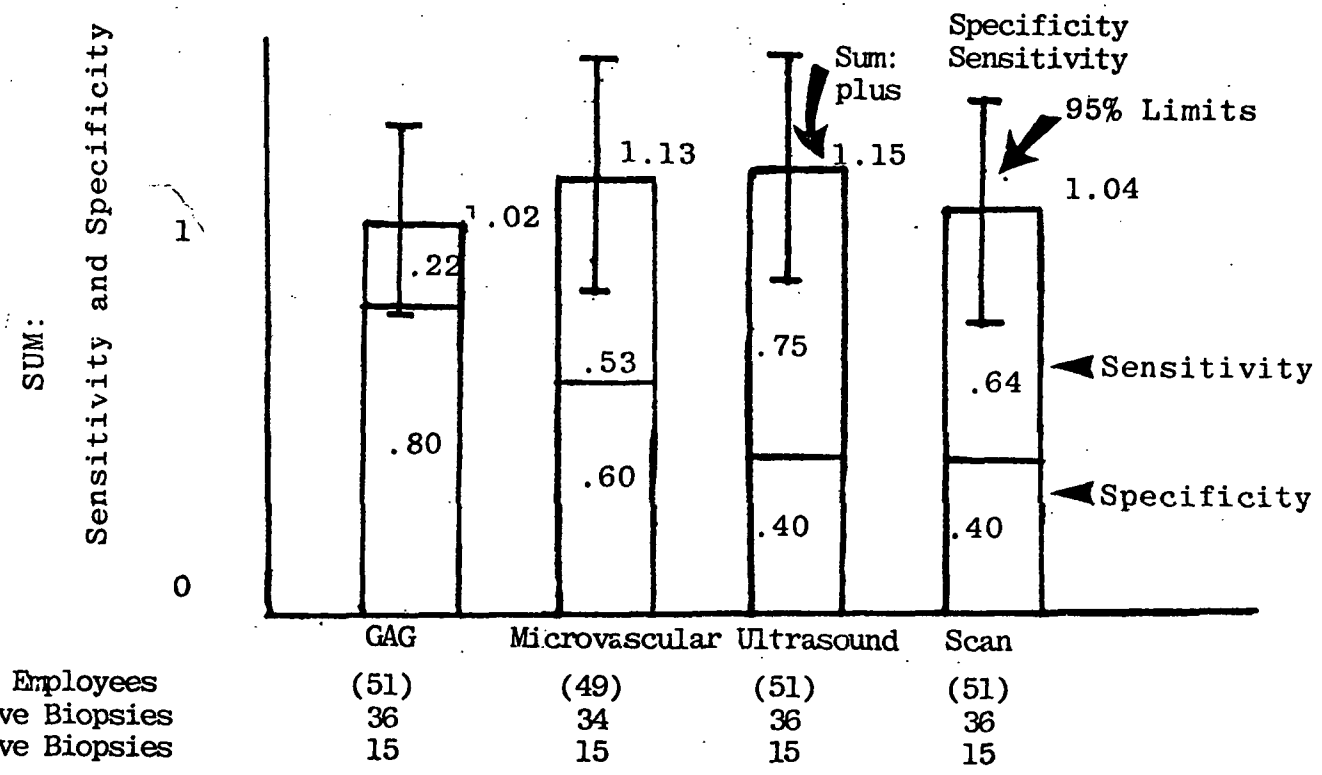
FIGURE 1



*Not seen by Doctor Taylor

FIGURE 2

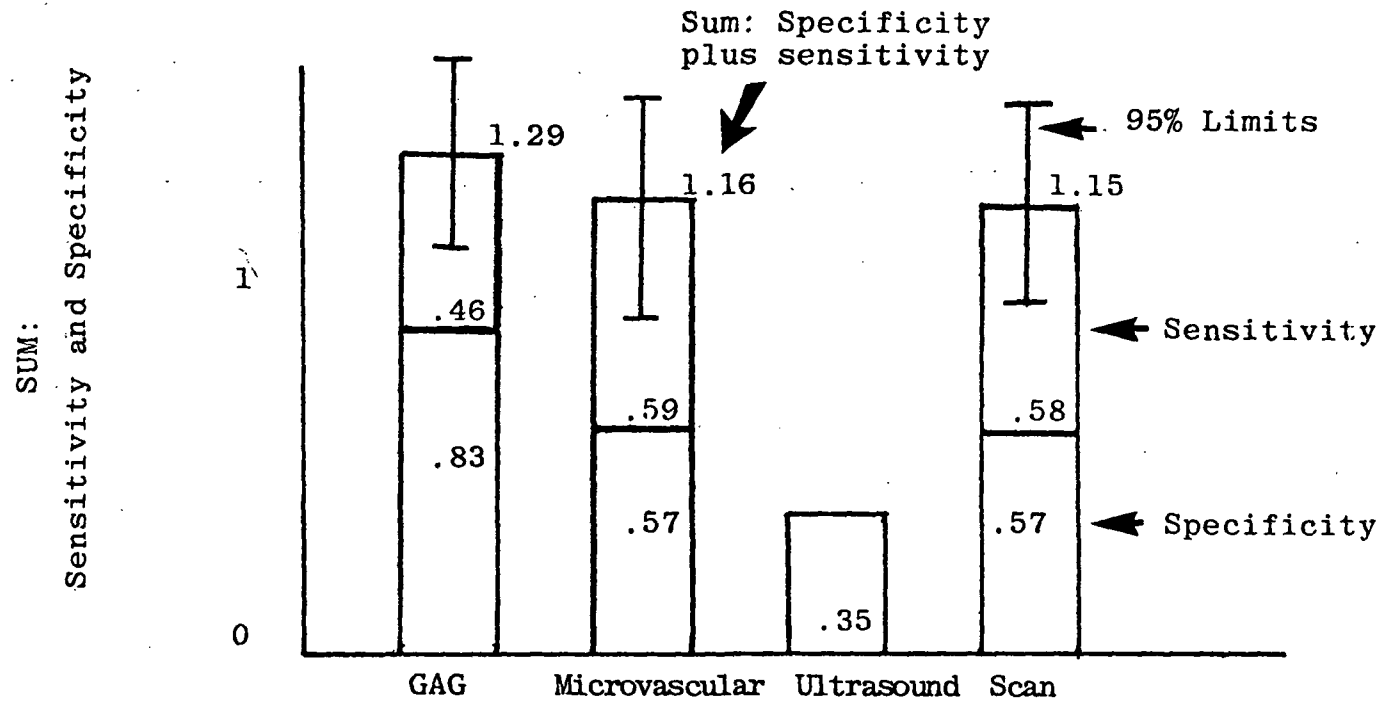
SENSITIVITY AND SPECIFICITY FOR FOUR SCREENING TESTS FOR THE PREDICTION OF LIVER ABNORMALITIES (AS DETERMINED BY BIOPSY)



	GAG	Microvascular	Ultrasound	Scan
Number Employees	(51)	(49)	(51)	(51)
Positive Biopsies	36	34	36	36
Negative Biopsies	15	15	15	15

Figure 3

SENSITIVITY AND SPECIFICITY FOR FOUR SCREENING TESTS FOR THE PREDICTION OF LIVER ABNORMALITIES (AS DETERMINED BY REVIEWED BIOCHEMICAL TESTS)



Number Employees	(60)	(57)	(37)	(61)
Positive Biochemical	24	22		24
Negative Biochemical	36	35		37

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16. ABSTRACT A prospective collaborative study was conducted to compare the effectiveness of four clinical techniques in the detection of liver damage due to vinyl chloride monomer exposure. A chemically exposed and medically monitored worker population was identified by histo-pathological and biochemical documentation. Three techniques were non-invasive: a) grey scale ultrasonography of the liver, b) microvasular skin capillary assessment, and c) urinary analysis of glycosaminoglycan excretion. The fourth techniques was the standard ^{99}mTc sulfur colloid radionucleotide liver spleen scan. The screening studies were performed on a randomly selected single cohort of chemical workers. All four techniques were analyzed for their sensitivity and specificity as compared to results of the liver biopsy and biochemical blood test classification. Although all four screening techniques had a sensitivity and specificity sum greater than one, none were significantly better than could be explained by chance or the use of the biased coin. Reclassification of the population into those with more severe biochemical abnormalities improved the sensitivity of all screening tests, but only the sensitivity and specificity sum for the GAG test were statistically significant at the 0.05 level. There was no significant correlation between any pair of screening test. None of the four screening tests agreed with the biopsy results better than might be obtained by biased coin or chance. These screening studies as presently constituted, **do not** provide sufficient sensitivity and specificity to warrant their use in community screening for subclinical asymptomatic hepatic injury due to chemical exposure.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Vinyl chloride Vinyl monomer Occupational exposure Community exposure	Ultrasonography Radionucleotide liver spleen scan Microvascular skin capillary assessment Glycosaminoglycan excretion Screening techniques-sensitivity and specificity Occupational study - Community Study	

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