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An Assessment of Hand Thermography in Vinyl Chloride Workers

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Summary

Since Raynaud's phenomenon is an early and integral part of the condition of acro-osteolysis in vinyl chloride workers, a survey involving 143 workers and 56 controls was carried out to assess the feasibility of using hand thermography to detect changes from the normal pattern of vascularity.

From the almost identical results between the control and the exposed subjects, and between groups within the exposed population, it appears that there is no detectable difference in thermographic appearances.

Introduction

In the general population, the syndrome of intermittent ischaemia of the fingers and associated skin changes, first described by Raynaud in 1862, is divided into primary and secondary types, the condition being considered secondary if an associated or precipitating pathological process can be found. The aetiology of the primary or idiopathic type is unknown, but is related to an abnormal vascular reactivity to cold, although mental stress, smoking and increasing age may also exacerbate it. Secondary Raynaud's disease may be associated with a wide variety of underlying diseases of the skeletal, vascular, endocrine and central nervous systems, severe infections, mechanical trauma and collagen diseases (Beeson and McDermott, 1963; Velayos et al., 1971; Leading Article, *British Medical Journal*, 1972).

The milder primary cases are not uncommon, with women affected ten times as often as men (Gifford and Hines, 1957).

Although other idiopathic and familial syndromes have been described in association with

acro-osteolysis (Andren et al., 1962; Cheney, 1965), occupational acro-osteolysis (AOL) was first recognized as a clinical entity in 1963 (Suciu et al., 1963), and appears to be confined almost exclusively to cleaners of reactor vessels in which vinyl chloride monomer (VCM) is polymerized to polyvinyl chloride (PVC) (Wilson et al., 1967; Harris and Adams, 1967; Dinman et al., 1971), and only one case is recorded in a man who, while he had never actually been a reactor cleaner, had worked in the reactor buildings with a similar exposure to VCM (Stewart et al., 1975).

Occupational acro-osteolysis is described as a symptom complex consisting of a Raynaud's-like phenomenon involving the hands, changes of the skin, simulating systemic sclerosis of the hands and forearms, and osteolytic and sclerotic lesions of the bones, particularly in the hands and feet, and the sacro-iliac joints (Markowitz et al., 1972). The lower pole of the patella and the styloid processes of radius and ulna can also be affected (Dinman et al., 1971).

The incidence of the disease is not accurately known; Wilson observed 31 cases in 3000 workers involved in vinyl chloride manufacture and polymerization (Wilson et al., 1967), and Dinman reported 25 definitive cases in 5011 employees in 32 plants throughout the United States and Canada, with 16 other men considered suggestive but not definitive cases (Dinman et al., 1971).

Markowitz found two cases in a plant employing less than 100 people, (Markowitz et al., 1972). The

incidence is, however, believed to be relatively low—less than 3 per cent of all production workers who had at one time worked as reactor cleaners, and because of this it has been suggested that a personal idiosyncrasy is possibly one of the factors in its aetiology (Wilson et al., 1967).

Furthermore, it seems that the Raynaud's phenomenon is usually the first of the triad complex to appear, and that it is irreversible even if the patient is removed from exposure to VCM; probably the skin changes are also irreversible, though neither are invariably progressive, but recovery of the bony lesions has been reported (Markowitz et al., 1972; Réty et al., 1974; Williams and McLachlan, 1976).

Considering, therefore, the importance of the Raynaud's phenomenon, both as an integral part of the condition and as a possible precursor of established acro-osteolysis, it is apparent that early detection of vascular insufficiency by a provocation test might have a part to play in the screening of men about to be engaged as vessel cleaners, or of those already so engaged.

Patients and Methods

Radiographs of the hands of polycleaners and other production workers exposed to VCM have been taken regularly since 1971 at a factory producing in excess of 130 000 tonnes of PVC annually. It was decided that in addition to the radiography sessions in May, 1975, thermography of the hands would be done as well, on a voluntary basis, each of those men eligible by virtue of their exposure history having been given a letter explaining the nature and purpose of the project, and asking for their cooperation. Plant management and shop stewards were also given a somewhat fuller account personally by one of us, in order to enlist their help in promoting the project and to enable them to explain it to employees who might come to them with questions or doubts.

In all, 176 men were eligible to participate, and of those, 169 volunteered (96 per cent). In the event, 26 men were compelled to withdraw, due to absence on sick leave or holidays when the sessions were held, leaving 143 subjects finally (81 per cent of those eligible).

Each man was given in advance two detailed questionnaires.* The first sought information on

*Copies of these questionnaires are available on request from Dr D. M. J. Williams.

symptoms which might be attributable to vascular insufficiency of the hands, and if the patient knew of similar history in his immediate family. The second questionnaire concerned smoking habits and the men were asked not to smoke on the day of the test. From this questionnaire we found that of the 86 men who habitually smoked, 34 (39.5 per cent) were able to refrain.

A nurse from the factory medical centre was present at the sessions so that any man who had experienced difficulty with the rather elaborate questions could be helped to complete the form as he handed them in.

The sessions were held in a research laboratory where the room temperature could be regulated and throughout the sessions remained at between 19°C and 22°C (66.2° and 71.6°F). The weather on all four days of the experiment was seasonally mild, and the men had their hands X-rayed first. Consequently they were in the building for about 10 minutes before the thermography procedure was started.

Technique

Thermography records the temperature variations emitted by the body itself within the infra-red part of the spectrum.

The apparatus used in the survey was the Agfa Thermovision System, consisting of an infra-red camera and display unit. It permits the instantaneous display of the heat emitted by the body on a cathode-ray tube, and this display was recorded greytoned on Polaroid film.

The right hand of each vinyl chloride worker was placed on an armrest and the Thermovision display adjusted to visualize all digits. The whole of the hand was then immersed in a thermostatically controlled water bath at 19°C for 10 seconds. It has been shown (Lewis, 1946) that this is sufficient to produce detectable changes in normal subjects. The hand was then removed and rapidly wiped dry.

The hand was then repositioned on the armrest and constant visualization of the cathode ray screen commenced. Immediately a heat return was noticed in any portion of the hand or finger the time was recorded as T1 on one of three stop watches which had been activated immediately the hand was removed from the water (Fig. 1). The next return was recorded as T2 (Fig. 2). The final return time, T3, was noted when either all fingertip became visible (Fig. 3) or 10 minutes had elapsed.

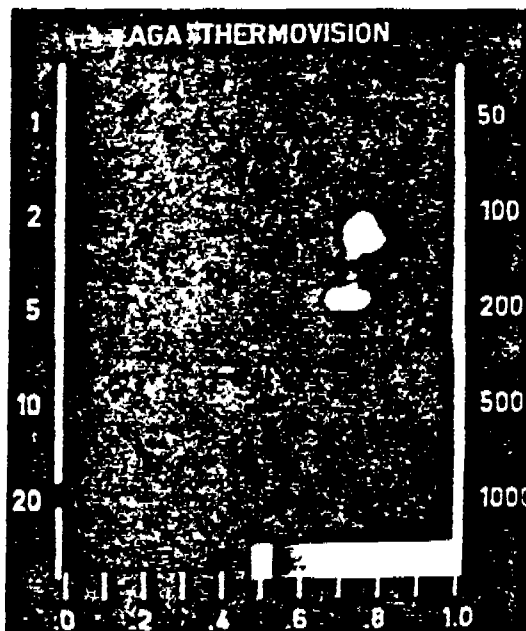


Fig. 1. The first return of heat (T1).

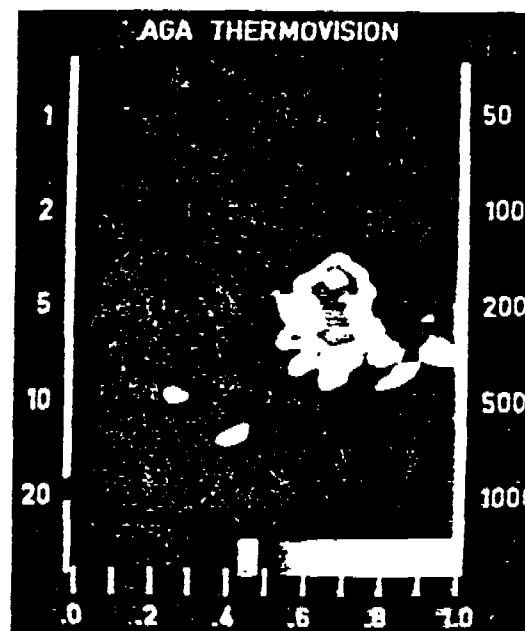


Fig. 2. The next return of heat to another area of the hand (T2).

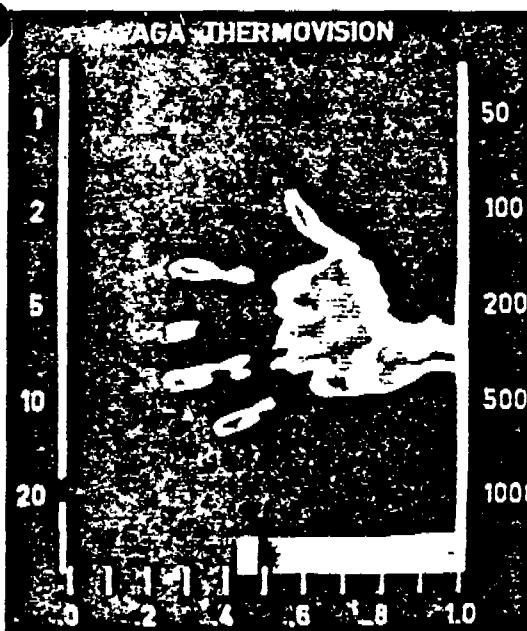


Fig. 3. The final return of heat to all fingertips.

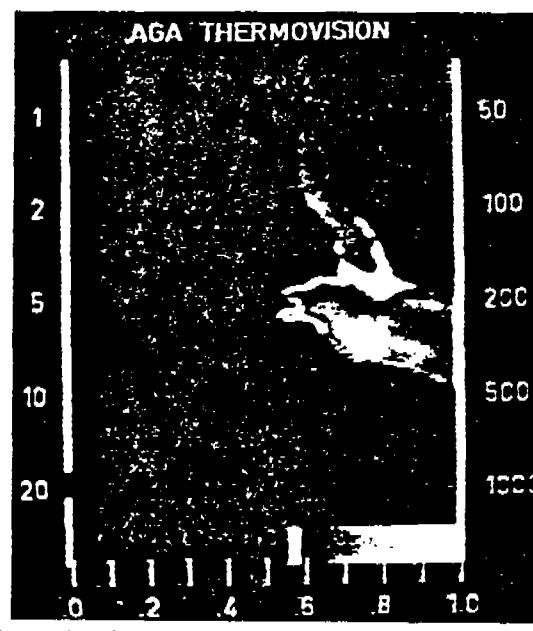


Fig. 4. An abnormal thermogram showing failure of heat return to all fingers within 10 minutes.

This arbitrary time was chosen because in a preliminary study of controls it was found that the mean return time was 4 minutes 29 seconds.

Normal thermogram in this context refers to the return of heat to all the digits within 10 minutes; abnormal thermogram refers to the failure of heat

Table 1. Results of thermography in 143 men and 56 controls

	Exposure group				Controls
	A	B	C	D	
Total number in group	72	33	3	35	56
'Normal' thermogram	54 (75%)	23 (69.7%)	3 (100%)	24 (68.6%)	45 (80%)
'Abnormal' thermogram	18 (25%)	10 (30.3%)	0	11 (31.4%)	11 (20%)
No 'full' return	7 (9.7%)	5 (15.2%)	0	6 (17.1%)	7 (12.5%)
No return at all	11 (15.3%)	5 (15.2%)	0	5 (14.3%)	12 (21%)

to return to all digits within 10 minutes (Fig. 4). The mean return for vinyl chloride workers was 3 minutes 33 seconds.

It was found possible to examine about ten patients per hour, which does not of itself rule out the technique for mass screening programmes.

Results

VCM-exposed Subjects

From factory records it is possible to classify those who took part into four groups in descending order of magnitude of peak exposure to VCM.

- Vessel cleaners for one year or more.
- Other polymerization workers for one year or more.
- Monomer process workers for one year or more.
- Other exposed workers.

The men remain classified in the highest exposure category that they achieved in the course of their employment. Since exposure in all jobs is less than 20 ppm for the past 18 months, this is only a valid comparison of their relative exposure histories prior to mid-1974.

The 143 volunteers were distributed among the exposure groups thus:

- 72 (50.3 per cent).
- 33 (23 per cent).
- 3 (2.1 per cent).*
- 35 (24.5 per cent).

Table 1 shows the results of thermography in these four exposure groups. There were no radiological changes in the hands in this series suggestive of acro-osteolysis.

From this table it can be seen that there was no significant difference in the results between the exposure groups nor between each individual group and the overall test population; in the case

of Group C, there were only three subjects, and in fact the highest VCM-exposed group most closely matched the control subjects.

'Abnormal' thermograms were recorded by 11 of the 86 men who smoked (26.7 per cent) and by 14 on the 52 non-smokers (26.9 per cent).

From the questionnaires, it was found that men considered that they had symptoms of Raynaud's phenomenon, but 11 of these men (73.3 per cent) had 'normal' thermograms, and these 11 included 3 men who had reported in the questionnaire that in each case all ten of the fingers were so affected. However, in the other subjects, thermography did show a delayed return (Table II), although there is no clinical evidence that these men do actually have Raynaud's phenomenon, and in 2 cases it is possible that the thermogram was affected by smoking just before the test.

Only one man was aware of a family history of Raynaud's phenomenon, but he did not consider himself to have the condition, and indeed his thermogram was quite normal.

Controls

The control subjects comprised 56 male hospital staff volunteers, and were examined by an identical procedure. Forty-five (80 per cent) returned 'normal' thermograms.

Discussion

It is known that there is an increased incidence of Raynaud's phenomenon in the general population both with increasing age and with smoking. Tables III and IV show that this was reflected in both controls and VCM-exposed workers, although it is of interest that the incidence did not increase until an older age group in the exposed workers. The reason for this is not known and the numbers involved are probably too small for speculation.

*VCM has not been produced at this plant since December, 1970.

Table II. Correlation between questionnaire and thermography

	Exposure Group	Age	Smoker	Fingers affected	
				By questionnaire	By thermography in the right hand
Patient 1	A	53	No, for 8 months	Middle, right and left hands	All digits affected
Patient 2	B	48	Yes, including before test	All, both hands	Index and middle only affected
Patient 3	D	48	No, for 3 years	Index, middle and ring, right hand	Index, middle and ring
Patient 4	D	26	Yes, including before test	Index, middle, ring and little, left hand	All affected

Table III. Abnormal thermograms by age groups

Age	VCM workers		Controls	
	Total	Abnormal thermogram	Total	Abnormal thermogram
20-29	40	6 (15%)	37	7 (19%)
30-39	39	5 (12%)	15	3 (20%)
40-49	40	6 (10%)	2	1 (50%)
50-59	24	6 (25%)	2	—

Table IV. Abnormal thermograms by smoking habit

	VCM workers		Controls	
	Non-smoker (59)	Smoker (84)	Non-smoker (36)	Smoker (20)
Return zero T1	14 (23%)	12 (14%)	3 (8%)	1 (5%)
Non-return T2	10 (16%)	12 (14%)	4 (11%)	3 (15%)
Non-return T3	19 (31%)	23 (27%)	6 (17%)	4 (20%)

the point to be worthwhile. Similarly, with regard to the effect of smoking, though the patterns are parallel, detailed comparisons would not be valid with these numbers.

With regard to acro-osteolysis, it appears likely that, although the bony lesions can heal in time if exposure to VCM ceases, the Raynaud's component will persist (Williams and McLachlan, 1976). As we have explained earlier in this paper, it has been customary for long-term health surveillance for delayed effects to keep a man in the highest exposure category experienced in his working life at the factory. By doing this, one remains alert for the possibility of late-onset developments from previous higher exposures. Nevertheless, in this plant, men change jobs as part of their normal career progress, from the higher exposure of vessel cleaning where most new entrants start their work, to production processes downstream and even, not infrequently, to supervisory work.

This practice is in contrast to that of other plants where a two-tier entry tends to place men for longer periods in either labouring jobs (vessel cleaning) or line production work, with less progression from the former to the latter. It is, however, relatively simple in this factory to label the men by their present jobs, as well as by their previous or highest exposure work.

If this is done, while the figures reflect job progression (Table V), the pattern holds virtually steady. It therefore seems most unlikely that there is any delayed effect, in terms of the development of Raynaud's phenomenon, let alone the full syndrome of acro-osteolysis, resulting from higher exposures in former years.

However, the unique case described by Stewart et al., (1975), wherein a worker developed AOL without ever having been a vessel cleaner, encourages the belief that it is not only exposure levels, but exposure in an idiosyncratic individual that produces AOL, and therefore surveillance in some form of exposed workers cannot yet be discontinued, despite the creditably low levels of exposure now achieved in the industry.

Many of the men who volunteered for the survey had had upwards of 15 year's service in the industry, at a time when exposure levels were markedly higher than are found today in any jobs relating to VCM. From the summer of 1974, it is doubtful if any worker has been consistently exposed to VCM above 25 ppm, and therefore any future effects in terms of Raynaud's phenomenon, as a precursor to, or an essential component of, acro-osteolysis, are going to be an unlikely finding clinically. Since it is clear that questionnaires are relatively unhelpful, there seems to be no substitute, in our present state of knowledge, for regular hand

Table V. Comparison of results of thermography by placing exposed workers in either present job or highest exposure categories

Category	Present job		Highest category	
	Total in group	Abnormal thermograms	Total in group	Abnormal thermograms
A	16	5 (31.25%)	72	18 (25%)
B	97	26 (26.8%)	33	10 (30%)
C	0	0	3	0
D	30	8 (26.6%)	35	11 (31%)
Controls	56	11 (20%)	56	11 (20%)

inspections by trained medical or nursing staff, and that firm proof of Raynaud's phenomenon must still rest upon a clinical observation of its occurrence. Without this safeguard, as Binns (1975) pointed out, men are at risk of being unjustifiably removed from their jobs.

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