Epidemiology of Successive Heat Waves in Michigan in 1962 and 1963

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A sharp rise in the number of deaths occurred during each of two heat waves taking place in Detroit in successive years (May, 1962, and June-July, 1963). Persons aged 60 years or more were at special risk, and cerebrovascular accident was unduly prominent among reported causes of death. When the experience of 1962-1963 is compared with an equivalent in 1953-1955, the increase of cerebrovascular accident among recent heat-related deaths is striking. Among etiological factors to be explored in a follow-up case study of heat victims in Detroit are predisposing or contributing clinical diseases, unusual exposure to environmental heat, and the frequency of electrolyte and drug regimens, particularly those including the newer diuretics and hypotensive agents.

During 1963 considerable deviations from the computed number of predicted deaths occurred twice—in the first three months of the year, due to influenza, and in June and July, due to heat. Figure 1 shows the predicted number of deaths based upon data of previous years and actual deaths reported from 108 cities to the US Public Health Service.[1] Over the years the observed and predicted curves coincide fairly well, except for the influenza winters and the June-July period of 1963, which coincided with reports of usually high and prolonged temperatures throughout the East North Central States and the Eastern Seaboard.

The epidemiology of heat-related deaths in an urban setting has received little attention in the literature since the thirties,[2,3] with the exception of a recent work by Kutschenreuter.[4] This may be due, in part, to advances in air conditioning and to the reduction of industrial heat hazards. In recent years the effects of heat stress have been studied primarily in the armed forces.[5,6] Thus, effects of a recent heat wave on an urban population warranted study of current mortality rates and causes of heat-related deaths.

Mortality statistics and mean daily temperatures were gathered for those days with unusually high temperatures and were compared with similar data for periods with normal mean temperatures.[7] National, state, and city mortality figures were used for comparisons; distribution of deaths by age at death proved to be important; causes of death to which the excess deaths were attributed were examined in detail. The primary source of data was the death certificate.

Total Deaths and Deaths Among the Aged.—The seasonal incidence of total deaths and of deaths among persons 65 years or older during 1963 is shown in Table 1. The data emphasize the susceptibility of older persons to environmental stresses and infection. With an aging population some allowance is made for a rising expectancy of deaths, as indicated by the rising slope of the curve for predicted deaths in Fig 1. During 1963, the computed predicted values were exceeded by 18,073. Most of these deaths occurred in periods I, II, and III, and are attributed to influenza A_2 infection. More than 4,600 deaths above the computed prediction occurred in June and July; these occurred coincidently with heat waves in cities on the eastern seaboard and in Kansas City, Mo, Kansas City, Kan, Chicago, and Detroit. Deaths in southern and western cities apparently remained at normal values during this period. Persons in the age group 65 and older represent less than 10% of the general population, but have a four-fold representation among the net excess deaths for 1963 (38.5%). Although the excess percentage of deaths of elderly persons reached over 61% in March, this was exceeded by over 68% in July.

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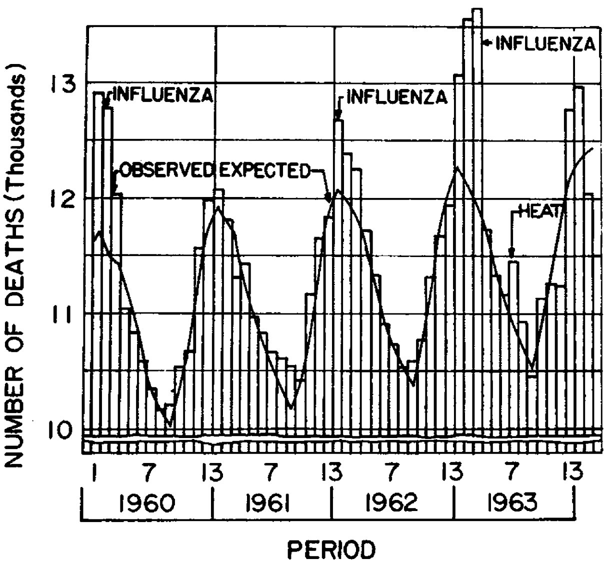

Fig 1.—Total number of deaths in 108 US cities. Average number per week by four-week periods.

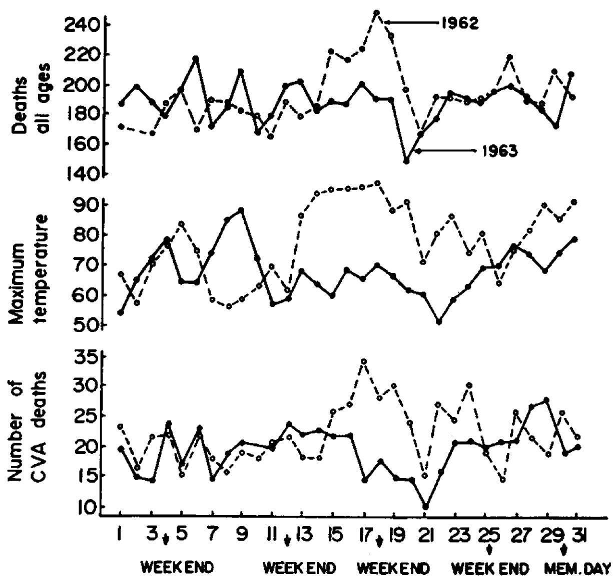

Fig 2.—Deaths and maximum temperatures in Michigan during May, 1962 and 1963.

Table 2 shows that, on the average, 55% to 56% of all deaths occur among persons aged 65 or more. Deaths among the elderly show weekly oscillations of much greater amplitude than do total deaths; these oscillations range from a 169% excess in the week ending July 6, 1963, to a 588% deficit in the period following the unusually hot weather, the week ending Aug 10, 1963. Such fluctuations imply a fixed pool of susceptibles among the elderly who are unable to survive sudden stresses such as influenza and unusual heat. What are the particular mechanisms involved in these deaths? Are stress-related deaths among the elderly simply due to an acceleration of the normal or expected process of dying? The annual net excess of 6,951 deaths for persons 65 years or more appears to be within normal limits for 1963. The long-term uniform occurrence of deaths in a population is impressive; on a time scale of years or decades, short-term occurrences of excess deaths may suggest the "harvests" of susceptible persons. How is it possible, then, that in a single year influenza can harvest a bumper crop of susceptibles in the first three months and yet leave enough susceptibles for another upsurge of deaths in June and July because of the heat?

Deaths in Michigan and Detroit.—May of 1962 set a 30-year record for unusually high and sustained temperatures in Michigan. Deaths occurring in Michigan during this period of hot weather were compared with deaths occurring during the meteorologically unremarkable month of May, 1963. The comparison is shown in Fig 2. Daily maximum dry bulb temperatures are presented in degrees Fahrenheit; other meteorological data (relative humidity and temperature-humidity indices) did not add any appreciable information and were omitted. Figure 2 shows a prompt and sustained rise in deaths, following the onset of high and sustained temperatures within two or three days. The deaths due to cerebrovascular accident also parallel the temperature curve in a consistent way.

Compared with a 30-year average of 70 F, the month of May, 1962, had an average daily maximum temperature of 77 F. There were six days when the maximum temperature was above 90 F compared with a predicted figure of one-half day, and the highest recorded maximum temperature of 92 F in May, 1963, was exceeded by 96 F in 1962.[7]

Table 1.—Deaths Reported in 1963 From 108 US Cities by Four-Week Periods*

Period Ending	I Jan 26, 1963	II March 2	III March 30	IV April 27	V June 1	VI June 29	VII Aug 3	VIII Aug 31	IX Sept 28	X Nov 2	XI Nov 30	XII Jan 4, 1964	Year's Total
Total Deaths													
Observed	51,744	67,427	54,799	46,888	55,445	45,833	56,645	42,151	42,907	56,287	43,392	61,762	625,280
Predicted†	48,888	60,515	47,860	46,864	56,665	43,944	53,869	42,315	42,618	55,561	47,000	61,108	607,207
Difference	+2,856	+6,912	+6,939	+24	−1,220	+1,889	+2,776	−164	+289	+726	−3,608	+654	+18,073
Deaths Among Persons 65 Yr and Older													
Observed	29,243	38,989	31,808	26,568	30,709	25,383	31,847	22,652	23,413	30,973	24,101	35,037	350,723
Predicted†	27,599	34,785	27,519	26,788	32,095	24,661	29,953	23,785	24,200	31,492	26,400	34,495	343,772
Difference	+1,644	+4,204	+4,289	−220	−1,386	+722	+1,894	−1,133	−787	−519	−2,299	+542	+6,951
Difference Percentage (65 Yr +) = $\frac{\text{(Difference, 65 Yr +)}}{\text{(Total Difference)}} \times 100$													
Difference Percentage	+57.6	+60.8	+61.8	−1033.3	−113.6	+38.2	+68.2	−690.9	−372.4	−171.5	−63.7	+82.9	+38.5

*Source: Morbidity & Mortality Weekly Report, vol 12 (No. 1-51) 1963; vol 13 (No. 1-4) 1964.
†Predicted deaths calculated from 1957-1961 experience.

Table 2.—Weekly Deaths Reported in Summer, 1963, From 108 US Cities*

Week Ending	June 29	July 6	July 13	July 20	July 27	Aug 3	Aug 10	7-Week Total
Total Deaths								
Observed	11,355	10,999	12,340	10,988	11,044	11,274	10,624	78,624
Predicted†	10,883	10,835	10,795	10,760	10,764	10,715	10,660	75,412
Difference	+472	+164	+1,545	+228	+280	+559	−36	+3,212
Deaths Among Persons 65 Yr and Older								
Observed	6,285	6,331	6,961	6,197	6,141	6,217	5,725	43,857
Predicted†	6,094	6,053	6,015	5,982	5,959	5,944	5,937	41,984
Difference	+191	+278	+946	+215	+182	+273	−212	+1,873
Percentage of Deaths Among Aged $= \frac{\text{(Deaths, 65 Yr +)}}{\text{(Total Deaths)}} \times 100$								
Observed	55.4	57.6	56.4	56.4	55.6	55.1	53.9	55.8
Predicted†	56.0	55.9	55.7	55.6	55.4	55.5	55.7	55.7
Difference	−0.6	+1.7	+0.7	+0.8	+0.2	−0.4	−1.8	+0.1
Difference Percentage (65 Yr +) $= \frac{\text{(Difference, 65 Yr +)}}{\text{(Total Difference)}} \times 100$								
Difference Percentage	+40 5	+169.5	+61.2	+94.3	+65.0	+48.8	−588.9	+58 3

*Morbidity & Mortality Weekly Report vol 12 (No. 28, 29, 32, 33) 1963.
†Predicted deaths calculated from 1957-1961 observations.

Table 3.—Characteristics of Two Detroit Heat Waves and Excess Deaths

Detroit Heat Waves	1962	1963
Onset	Mid-May	Late June
Duration	1 week	2 weeks
Meteorology	30-year record	Sustained heat, but not a record
Excess deaths (Heat period deaths — control period deaths)		
All causes	104	114
Due to cerebrovascular accident	27	59
Age 60 or more	90	91

Table 4.—Deaths and Maximum Temperatures in Detroit by Weekly Periods, May-August, 1962 and 1963

Week Ending	Maximum Temperature,* °F		Total Deaths†		Cerebrovascular Accident‡	
	1962	1963	1962	1963	1962	1963
May 11-12	62.6	72.0	304	349	30	35
18-19	92.4§	64.9	416	327	53	26
25-26	76.9	61.0	363	319	28	31
June 1-2	79.3	73.9	337	365	44	56
8-9	81.7	85.9	331	378	40	41
15-16	80.1	75.4	314	354	23	39
22-23	83.9	76.6	346	345	35	45
29-30	86.0	88.9§	352	406	32	62
July 6-7	82.9	88.3§	311	373	40	69
13-14	84.9	81.6	300	325	30	44
20-21	82.0	83.7	326	326	51	41
27-28	79.0	88.4	308	327	30	32
Aug 3-4	83.6	85.1	293	319	26	40
10-11	81.6	85.6	303	319	36	29
17-18	78.4	78.4	324	286	28	35
24-25	86.6	79.9	305	309	28	33
(Sept) 31-1	83.4	75.7	313	293	32	41

*Weekly average of maximum daily temperatures, Willow Run Station, US Weather Bureau.[4]
†Weekly total deaths, five-day moving average.
‡Number of weekly deaths due to cerebrovascular accident.
§Unusual or record heat.

Study of groupings of death causes shows no real excess for most causes, except heart disease (not significantly different at the 5% level); for cerebrovascular accidents the excess is significantly different from predicted frequencies ($p < 0.01$). Deaths due to cerebrovascular accident explain the bulk of the excess deaths. The effects of the heat wave on the incidence of deaths due to cerebrovascular accident can be seen in the following analysis. Maximum temperature correlations with total deaths and with deaths due to cerebrovascular accident in May, 1962, were 0.569 and 0.512, respectively, and for May, 1963, 0.184 and 0.125, respectively. The correlations for May, 1962, were significant (where $N = 31$, $R = 0.463$ and $p = 0.01$ for total deaths and $R = 0.520$ and $p = 0.001$ for deaths due to cerebrovascular accident).

Although heat waves in successive years have been reported (Illinois, 1936-1937), the occurrence of heat-related deaths in May, 1962, and June through July, 1963, in Detroit presents an unusual opportunity for study of the effects of environmental stress. Characteristics of the two Detroit heat waves are summarized in Table 3. In Fig 3 and Table 4 are presented weekly deaths and temperatures for the city from May through August, 1962 and 1963. Average maximum temperatures are related to five-day moving averages of total deaths and to weekly numbers of deaths due to cerebrovascular accident. The weeks in question offer

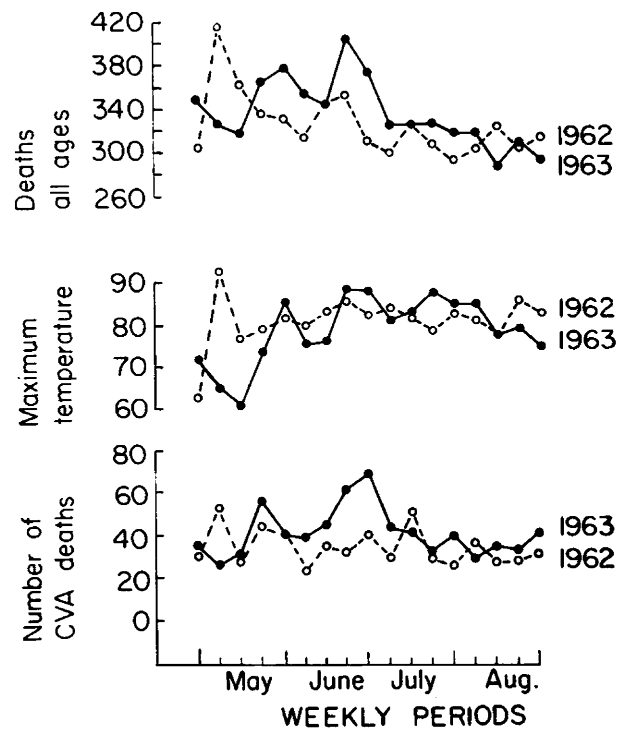

Fig 3.—Deaths and maximum temperatures in Detroit during May-August, 1962 and 1963.

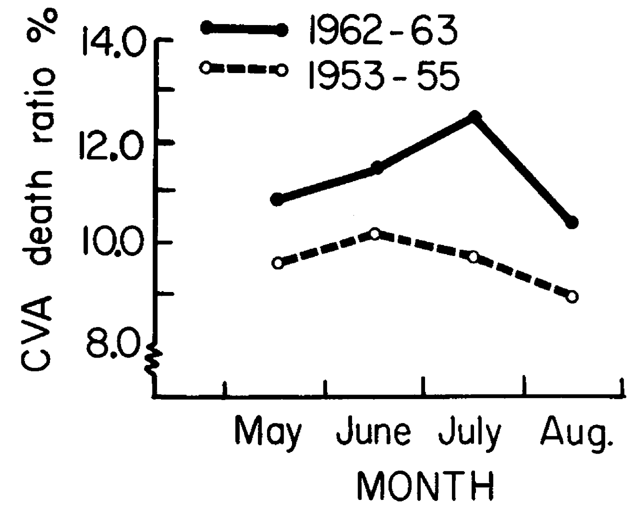

Fig 4.—Cerebrovascular-accident death ratio for Detroit during May-August, 1953-1955 and 1962-1963.

striking contrasts, because the summer months usually have the smallest number of deaths. As noted by others in the past, late summer heat seems to be better tolerated than early or mid-summer heat. At least three influences must be considered: (1) host factors of acclimatization; (2) exposure factors, such as job, vacation, air conditioning, etc; and (3) "harvest" of heat-susceptibles by death in the early part of the summer.

The selection of heat-related deaths for persons aged 60 years or more is emphasized in Table 5. The greater proportion of excess deaths in Detroit occurred among the elderly, both in 1962 (90/104) and in 1963 (91/114).

Other characteristics of persons dying in the heat and control periods which were compared and were not different included sex, race, area of residence, and crude socioeconomic indices. Persons dying in heat periods were found to be under medical care for a longer time than those in control periods, and a larger proportion of heat-related deaths were among persons under medical care than among controls.

Table 5.—Age Distribution of Deaths During Heat Waves and Control Periods in Detroit in 1962 and 1963

	Number of Deaths				Number of Excess Deaths*	
	Heat Waves Ending		Control Periods Ending		Heat Wave Ending	
Age	May 19, 1962	July 6, 1963	July 7, 1962	May 18, 1963	May 19, 1962	July 6, 1963
Under 60 yr ..	129	246	223	115	14	23
60 yr and over	300	537	446	210	90	91
Total	**429**	**783**	**669**	**325**	**104**	**114**
Percentage of Deaths Among Aged†	70.0	69.6	66.9	64.6	86.5	80.0

*Excess deaths = Number of heat-related deaths − number of control deaths.

†Percentage of deaths among aged $= \frac{\text{Deaths, 60 yr +}}{\text{Total deaths}} \times 100.$

Specific causes of heat-related deaths.—Even under obvious heat hazards such as work in unventilated mineshafts and boiler rooms of ships, deaths have occurred and have been reported as due to a variety of causes not necessarily related to heat. The nonspecificity of heat-caused deaths is illustrated by the mortality records of the famous heat wave of 1948 in New York City; the records show that over a one-week period ending Sept 3, 1948, there were 1377 excess deaths from all causes, but only 48 (3.5%) were certified as due to heat or sun stroke.[8] This and other published reports suggest that the group of cardiovascular deaths during a heat wave may contain the majority of heat-associated cases. From a clinical-physiological viewpoint, the crucial role of cardiovascular reserve in heat tolerance is obvious; undoubtedly, the textbook syndrome of hyperpyrexia probably occurs much less frequently than the equally fatal circulatory syndrome of shock or prostration. In Table 6 the causes of death in Detroit are listed, but do not include heat stroke, because no instances of accidental death due to environmental heat as the primary cause were reported. The other causes are grouped according to useful clusters of the International List categories. Changing patterns of diagnosis in the medical and coding professions has had relatively little influence on trends in reported

Table 6.—Reported Causes of Deaths During Weeks of High Temperature and Control Weeks in Detroit in 1962 and 1963

	Weeks of High Temperature			Total		Control Weeks			Total		Difference†	
Cause of Death*	May 18, 1962	June 29, 1963	July 6, 1963	Number	%	June 30, 1962	July 7, 1962	May 13, 1963	Number	%	Number	%
Heart disease	155	147	132	434	35.8	141	120	136	397	39.7	37	−3.9
Circulatory and renal	18	15	13	46	3.8	23	9	10	42	4.2	4	−0.4
Cerebrovascular accident	53	62	69	184	15.2	32	40	26	98	9.8	86	+5.4
Cancer	76	79	77	232	19.2	72	54	66	192	19.2	40	0
Respiratory	12	14	6	32	2.6	6	8	12	26	2.6	6	0
Cirrhosis	14	8	8	30	2.5	10	2	8	20	2.0	10	+0.5
Infant diseases	11	15	15	41	3.4	20	24	10	54	5.4	−13	−2.0
Accident	26	16	23	65	5.4	18	13	25	56	5.6	11	−0.2
Communicable diseases	4	5	3	12	0.9	5	9	3	17	1.7	−5	−0.8
Diabetes	15	6	7	28	2.3	8	7	5	20	2.0	8	+0.3
Others	45	64	29	138	11.4	26	22	24	72	7.2	66	+4.2
Total	**429**	**401**	**382**	**1,212**	**101.5**	**361**	**308**	**325**	**994**	**99.4**	**218**	....

*International List groupings, ie, deaths due to cerebrovascular accident include 330-334.
†Difference in totals = Hot weeks − control weeks.

Table 7.—Distribution and Ratios of Deaths Due to Cerebrovascular Accident in Detroit in 1962 and 1963

	Weeks of High Temperature Ending			Total		Control Weeks Ending			Total	
Specific Diagnosis	May 19, 1962	June 28, 1963	July 6, 1963	Number	%	June 30, 1962	July 7, 1962	May 18, 1963	Number	%
Hemorrhage	25	32	37	94	51.5	13	24	13	50	52.0
Embolism	22	26	26	74	40.5	12	11	9	32	33.4
Other	5	4	6	15	8.2	7	5	2	14	14.6
Total	52	62	69	183	100.2	32	40	24	96	100.0
Total deaths, all causes	429	401	382	1212		361	308	325	994	
Ratio*	12.1	15.5	18.1	15.2		8.9	13.0	7.4	9.8	

*Ratio as a percentage $= \frac{\text{(Cerebrovascular-accident deaths)}}{\text{(Total deaths)}} \times 100$

deaths due to cerebrovascular accident compared to reported deaths due to other cardiovascular diseases.[9] When deaths occurring during the three weeks of heat stress are compared by cause in Table 6 with deaths in three normal periods, only two categories show an excess in the hot periods. Deaths due to cerebrovascular accident have an excess of 5.4% and those due to a variety of other causes, 4.2%. The cardiovascular-renal group do not show the excess which one might expect from older publications.

Table 7 presents in further detail the distribution of deaths due to cerebrovascular accident by the more specific categories; cerebral hemorrhage, thromboembolism, and others, with perhaps some shift of deaths from the "other" category during normal periods to the embolism group in periods of heat stress, which seems of doubtful significance. However, the shift in the ratio of cerebrovascular-accident deaths to total deaths from the expected average of about 10% (which is consistent over the past ten years in Michigan) to an average of 15% for the periods of heat stress is quite striking and demands explanation.

Confirmation from another section of the country occurred in 1963. A similar shift in the cerebrovascular-accident death ratio is reported from the Los Angeles County Health Department in a summary of deaths in the unusual late summer heat wave which occurred during the 39th and 40th weeks of the year 1963 (Table 8). These data (Table 8) show a proportion of deaths due to cerebrovascular accident similar to that in Detroit, and for the period of heat stress a similar, definite shift toward more deaths due to cerebrosvascular accident and more deaths among the elderly. Additional California data are needed, but the resemblance of the mortality pattern during the unusual heat wave to that of Michigan is impressive.

Table 8.—Reported Deaths in Los Angeles County in 1963

		Reported Deaths				
Week	Temperature	All Causes	Cerebrovascular Accident	Cerebrovascular Accident, %	Age 65+	Victims 65 yr+, %
37th	Normal	525	67	12.8	313	59.6
38th	Normal	478	54	11.3	294	61.5
39th	Severe heat	567	77	13.6	369	65.0
40th	Heat and normal	538	83	15.4	334	62.1

Trend of Cerebrovascular-Accident Death Ratio in Detroit.—The trend of the cerebrovascular-accident death ratio as a percentage,

$$\frac{\text{Deaths due to cerebrovascular accident}}{\text{Total deaths}} \times 100,$$

is shown in Fig 4 for each summer month for the periods 1953-1955 and 1962-1963 in Detroit. Although a gradual rise in the ratio may be anticipated in an aging population, on an annual basis this rise has been quite gradual, from an average ratio for the years 1953-1955 of 10.3% to 10.5% for the year of 1962. In general, deaths due to cerebrovascular accident tend to be less in the summer than in the winter; hence, the sharp rise with heat stress in 1963 is of great interest. Examination of indivdual summer months, weather records, and ratios for the selected years 1953-1955 and 1962-1963 shows some apparently random variation from values as low as 8.5% to values as high as 13.5%, but any ratio above 11.0% (the annual average being 10.5%) appears to be definitely unusual. Why a very hot July in 1955 (with 18 days of 90 F or more) should give a ratio of only 10.1%, followed by a low ratio of 8.9% in August, 1955, is puzzling; does some important factor differentiate the reported deaths of 1955 and 1963? This factor is not entirely meteorological, but more probably concerns elements of medical diagnosis, therapy, and

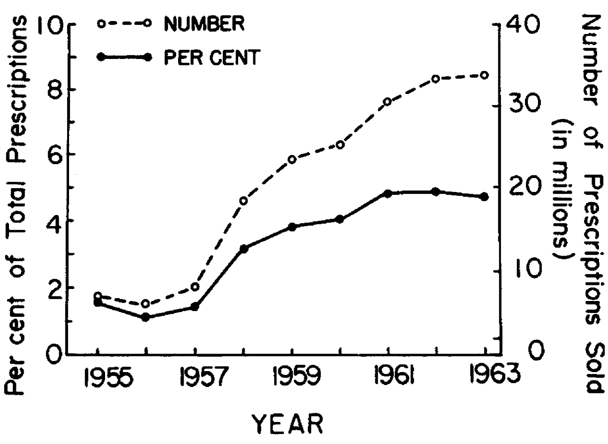

Fig 5.—Trend of annual prescriptions for diuretics in US.

reporting which can strongly influence vital statistics.

Effect of Hypotensive Agents.—The great extent to which the new hypotensive agents are being used is difficult to estimate. The annual survey by the *American Druggist*, performed as a market research service, is conducted as a canvass of all types of prescriptions among a sample of druggists. In Fig 5 data are presented to show the dramatic increase in diuretic usage since the introduction of the thiazides in 1953.[10] The same data indicate that over 67% of diuretic prescriptions are refills, compared to an average of 49% for other drugs, and that the 1963 estimate of total prescriptions is 741,000,000! The contribution of the thiazides and other hypotensive agents to the national decline in deaths due to hypertension and hypertensive heart disease is also difficult to estimate, but must be considerable; certainly the new agents have not only strengthened the therapeutic potential of practitioners, but along with surgical advances have stimulated earlier and more definitive diagnosis of hypertensive conditions. The observed change in causes of heat-related deaths in 1962-1963 compared to equivalent periods of 1953-1955 may be coincidental rather than etiologically linked to the therapeutic changes; proof of such a relationship remains to be established.[11,12]

Comment

If a recent increase in use of newer diuretics and other hypotensive drugs were shown to be a real factor in predisposing elderly persons to cerebrovascular accident during sudden or prolonged periods of high environmental temperatures, what would be a likely physiological-pharmacological mechanism, and how would the relative risk of harm during the relatively infrequent heat waves compare with the well-documented benefits of properly used hypotensive agents?[13-16]

Sodium diuresis in the face of heat stress may lead to hypovolemia, cerebral or cardiac ischemia with cutaneous vasodilation, and possibly cerebral anoxia, bleeding, and thrombosis in previously narrowed vessels, as well as disturbed potassium levels. Dehydration may contribute to increased viscosity of the blood and reduced flow. Transient hypotension may interfere with adequate circulation.

The newer agents have reduced death and disability due to hypertension and hypertensive heart disease and undoubtedly lowered the number of deaths due to cerebrovascular accident as complications of these diseases. On the other hand, if a short-term risk during sudden periods of heat stress due to relative sodium depletion, dehydration, and hypotension were established, the advantage of short-term modification of salt, fluid, and drug intake should be evident. For the present, proper usage of these potent drugs is the keynote as it is for most of the pharmacopeia. Unawareness of a heat hazard and lack of seasonal modification of a hypotensive-diuretic-electrolyte regimen may be serious if a sudden or severe heat wave should occur.

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