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Supplemental ascorbate in the supportive treatment of cancer: Reevaluation of prolongation of survival times in terminal human cancer*

(vitamin C)

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Contributed by Linus Pauling, May 30, 1978

ABSTRACT A study has been made of the survival times of 100 terminal cancer patients who were given supplemental ascorbate, usually 10 g/day, as part of their routine management and 1000 matched controls, similar patients who had received the same treatment except for the ascorbate. The two sets of patients were in part the same as those used in our earlier study [Cameron, E. & Pauling, L. (1976) *Proc. Natl. Acad. Sci. USA* 73, 3685-3689]. Tests confirm that the ascorbate-treated patients and the matched controls are representative subpopulations of the same population of "untreatable" patients. Survival times were measured not only from the date of "untreatability" but also from the precisely known date of first hospital attendance for the cancer that eventually reached the terminal stage. The ascorbate-treated patients were found to have a mean survival time about 300 days greater than that of the controls. Survival times greater than 1 yr after the date of untreatability were observed for 22% of the ascorbate-treated patients and for 0.4% of the controls. The mean survival time of these 22 ascorbate-treated patients is 2.4 yr after reaching the apparently terminal stage; 8 of the ascorbate-treated patients are still alive, with a mean survival time after untreatability of 3.5 yr.

A year and a half ago we reported (1) the results of a clinical trial in which 100 terminal cancer patients were given supplemental sodium ascorbate (usually 10 g/day) as part of their routine management, with their progress compared with that of 1000 similar patients who were treated identically (by the same clinicians in the same hospital) except that they received no supplemental ascorbate. The reported mean survival time after the patient had been recognized to be terminal ("untreatable" in Scottish medical practice) was more than 210 days for the ascorbate subjects and 50 days for their matched controls. Analysis of the survival-time curves indicated that deaths occur for about 90% of the ascorbate-treated patients at one-third the rate for the controls and that the other 10% have a much greater survival time. The results seemed clearly to indicate that this simple and safe form of medication is of definite value in the treatment of patients with advanced cancer.

Several experienced investigators in this field have expressed to us their doubt as to whether the ascorbate-treated patients and their controls comprised representative subpopulations of the same population and whether comparable times of untreatability had been assigned to the two groups. We decided to investigate these questions.

A new set of control patients was selected, and tests were carried out, as described in the following paragraphs, to answer the questions that had been raised. Our conclusion is that the results previously reported are valid, and, in fact, the increase in life expectancy of ascorbate-treated patients with terminal

cancer is found to be somewhat larger than was previously reported.

Selection of the controls

The original group of matched controls was selected by senior members of the Medical Records Staff in Vale of Leven Hospital, who were asked to produce records of 10 patients for each ascorbate-treated patient matched as to sex, age (to within 5 yr), and tumor type (site of the primary cancer and histological type), without regard as to whether or not death had occurred. The individual case records were then examined by a physician employed for this purpose, Frances Meuli, who first determined the date of untreatability by such conventional standards as the establishment of inoperability at laparotomy, the abandonment of any definitive form of anti-cancer treatment, or the date of admission for terminal nursing care and then calculated the survival time from that date until the factually recorded date of death. In carrying out her survey, Meuli was unaware of the survival times of the 100 ascorbate-treated test patients. In order to avoid possible bias, we did not supervise her work closely or attempt to refine it.

When we decided to check some of the other characteristics of these patients in more detail, as listed below, our examination of the records showed that, for some of the controls, the date of untreatability selected by Meuli was unreliable, sometimes because of incompleteness of the records and sometimes because of the death of these registered cancer patients from some intercurrent illness. Moreover, for some of the 100 original ascorbate-treated patients (no. 68, 77, 84, 89, 90, 91, 92, 93, 95, and 98), mostly with rather rare forms of cancer, the selected controls were found not to match sufficiently closely. We have accordingly replaced these 10 ascorbate-treated patients with 10 others, as determined by the availability of suitable controls, randomly selected from the more than 500 terminal cancer patients who have now received ascorbate treatment in Vale of Leven Hospital.

A fresh selection of a set of 1000 matched controls was then carried out. The new set, which overlaps largely with the first one, was again selected by the Medical Records Staff, and the selection was checked by one of us (E.C.) and our research assistant, Anita McLaren, who carefully studied each individual case record to determine its suitability as a control and to establish for each patient, whenever possible, the following recorded dates: (i) appearance of first symptom or sign of cancer; (ii) first hospital attendance because of the cancer that eventually reached the terminal stage; (iii) when any form of definitive anticancer treatment, believed at that time to be po-

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tentially curative, was instituted; (*iv*) when any form of definite anticancer treatment, recognized at that time to be only palliative, was instituted; (*v*) classification as untreatable, when treatment, other than for control of pain and general nursing care, had been discontinued; and (*vi*) death. Such dates were established for both the ascorbate group and the control group. In addition, for the ascorbate group the date when supplemental ascorbate was commenced was noted (usually coincident with or a few days later than the date of untreatability).

Comparison of ascorbate-treated patients and their matched controls

In table 1 of our earlier paper, the survival times (after the date of untreatability) of each of the 1100 subjects of that study were given. The corresponding values with the new set of controls are very similar, and we present in Table 1 of the present paper only the survival times of the ascorbate-treated patients after the date of first hospital attendance for the cancer that became untreatable, their survival times after the date of untreatability, and the corresponding mean values for the matched controls. (In 2.6% of the selected controls the records did not permit the date of untreatability to be reliably determined; these are patients whose date of death has been established but who had been lost to hospital follow-up in the intervening period. These controls were not used in determining the mean value of the second survival time.) The survival times of the patients who are still living are for the date 15 May 1978.

A test of the controls

As would be expected, there is a considerable difference in the survival times of patients with different primary cancers. We have accordingly divided the 100 ascorbate-treated patients into nine groups: 17 with colon as the site of the primary cancer (with 170 controls), 13 stomach, 17 bronchus, 11 breast, 8 kidney, 7 rectum, 7 bladder, 6 ovary, and 14 others. The treatment with ascorbate was begun only at the time when the patient was deemed untreatable; before that date, the history of those patients was no different from that of their controls. If the ascorbate-treated patients and their controls constitute representative subpopulations of the same population—that is, if they were randomly selected and if, in addition, the date of untreatability was determined in the same way for the two groups—the number of days between the date of first hospital attendance and the date of untreatability would be the same for the two groups, except for statistical fluctuations. We have accordingly made this comparison in several ways. In every trial, the calculation has provided no basis for the rejection of the null hypothesis with statistical significance. For example, the time between date of first hospital attendance and date of untreatability is greater than 1 yr for 27% of the ascorbate-treated group and for 23% of their controls; these numbers are not significantly different.

We carried out the nonparametric Wilcoxon matched-pairs signed-ranks test for each of the nine groups mentioned above in the following manner. The position, -5 to $+5$, of each ascorbate-treated patient in the individual set of 11 (the patient and 10 controls) as determined by the number of days from first hospital attendance to untreatability was taken as the magnitude of the difference between the two members (patient and controls) of the matched pair, and the Wilcoxon procedure was used to calculate the value of P . For eight of the nine groups, the value of P (two-tailed) was greater than 0.10, and for the ninth (cancer of the rectum), a value $P = 0.07$ was obtained. Inasmuch as with nine trials it is expected that one will give $P < 0.11$ because of statistical fluctuation, this result does not contradict the null hypothesis.

We conclude that the ascorbate-treated patients and their controls do represent randomly selected subpopulations of the same population of terminal cancer patients and that no systematic error has been made in the determination of the dates of untreatability.

The effect of ascorbate

Information about the progress of 100 terminal cancer patients who received supplemental ascorbate and 1000 matched controls (treated identically but without supplemental ascorbate) as selected in this second study is presented in Table 1. Because of the statistical and other reasons already given, we contend that this information provides an even better basis for comparison than the pilot-study information reported in our previous communication (1).

Columns C and D of Table 1 list the survival time of each ascorbate-treated cancer patient and the mean survival time of their 10 individually matched controls measured from the date of untreatability. (The distributions of values for the new sets of 10 controls are broadly similar to those for the old sets, as given in table 1 of ref. 1, and it is not necessary to publish individual values.) Columns A and B of Table 1 list the corresponding survival times as measured from the date of first hospital attendance; there can be no uncertainty about these dates, which are systematically recorded on each individual case record. The survival times measured from them accordingly provide a useful check on those measured from the date of untreatability.

Values of average survival times measured from each of the two reference dates are given for ascorbate-treated patients and matched controls in the nine categories (colon, bronchus, stomach, breast, kidney, bladder, rectum, ovary, and others) in Table 2. In every category and for both reference dates, the mean survival times are greater for the ascorbate-treated patients than for their controls. The probability that this would occur through a chance statistical fluctuation is only 4×10^{-6} . The extension of survival time by ascorbate relative to the date of first hospital attendance (column E) is greater than that relative to the date of untreatability (column F) in four categories and smaller in five. The differences between the values in these two columns are not statistically significant; they can be accounted for as resulting from a few very large values of the time between first hospital attendance and untreatability. For example, if patients 62 and 63 had the same survival time as the average for the other five in the bladder carcinoma group, the value in column E of Table 2 would be 328+ and thus only slightly less than the corresponding value in column F, rather than greater. This change would also decrease the value for all patients in column E from 321+ to 248+, just about equal to that in column F. There are eight values greater than 2000 days in column A of Table 1 and only two in column C; the chance of a large fluctuation is accordingly somewhat greater for the average survival time measured from the date of first hospital attendance than for the average survival time measured from the date of untreatability. On the other hand, the date of first hospital attendance is quite definite, whereas there is some uncertainty (in our opinion, however, not very great) in the date of untreatability so that it seems reasonable to assign equal weights to the values in columns E and F. We thus obtain the mean value 288+ days as the increase in survival time of the ascorbate-treated patients relative to their matched controls in the present study. The standard error of this mean, calculated on the unreliable assumption of a standard distribution of the values in Table 2, is about 50 days.

The values in column G relate to the ascorbate patients and controls previously reported (1), adjusted to include the addi-

Table 1. Comparison of times of survival of 100 cancer patients who received ascorbate and 1000 matched patients with no treatment (second set), by site of primary cancer*

Case	Sex	Age, yr	Survival, days [†]				Case	Sex	Age, yr	Survival, days [†]			
			A	B	C	D				A	B	C	D
Stomach							Ovary						
1	F	61	124	264	124	38	46	F	49	1234	307	230	64
2	M	69	42	62	12	18	47	F	68	89	690	88	21
3	F	62	25	149	19	36	48	F	52	201	285	196	129
4	F	66	45	18	45	12	49	F	67	356	244	337	58
5	M	63	412	180	257	64	50	F	56	2970	371	154	66
6	M	79	51	142	23	20	96	F	51	456	368	91	70
7	M	76	1112	35	128	13	Breast						
8	M	54	46	299	46	51	51	F	56	1235	796	10	45
9	M	62	103	85	90	10	52	F	57	24	977	24	68
10	F	69	876+	69	876+	19	53	F	53	1581	1623	580	23
11	M	46	146	361	123	52	54	F	68	1166	555	747	12
12	M	57	340	269	310	28	55	F	68	40	1304	39	52
95	F	59	396	130	359	55	56	F	53	727	1165	87	28
Bronchus							57	F	75	3808	675	633	62
13	M	74	81	72	74	33	58	F	68	791	871	251	75
14	M	74	461	134	423	18	59	F	55	1804	916	389	104
15	M	66	20	84	16	20	60	F	43	3460+	1311	2270+	41
16	M	52	450	98	450	58	61	F	53	719	978	322	64
17	F	48	246	48	87	13	Bladder						
18	F	64	166	142	115	49	62	M	93	4288	464	260	29
19	M	70	63	113	50	38	63	F	70	3658	694	305	22
20	M	77	64	90	50	24	64	F	77	51	221	37	21
21	M	71	155	30	113	18	65	F	72	278	490	109	16
22	M	70	859+	56	857+	18	66	M	44	548	433	37	11
23	M	39	151	260	38	34	67	M	64	1607+	484	1320+	14
24	M	70	166	116	156	20	68	M	63	1250+	152	419+	32
25	M	70	37	87	27	27	Kidney						
91	M	55	223	69	218	32	71	F	71	205	332	8	91
93	M	74	138	100	138	27	72	F	63	538	377	96	47
97	M	69	72	315	39	39	73	F	51	203	147	190	35
98	M	73	245	188	231	65	74	M	53	296	500	64	34
Colon							75	M	57	870	299	260	19
28	F	76	248	292	135	18	76	M	73	331	585	326	37
29	F	58	377	492	50	30	78	M	69	1685	1056	46	15
30	M	49	189	462	189	65	79	M	74	2060+	647	2060+	44
31	M	69	1843	235	1267	17	Gallbladder						
32	F	70	180	294	155	57	69	F	71	31	91	21	17
33	F	68	537	144	534	16	70	M	67	256	169	245	68
34	M	50	519	643	502	25	Esophagus						
35	F	74	455	301	126	21	26	M	69	199	103	60	25
36	M	66	406	148	90	17	27	F	80	838	90	44	11
37	F	76	365	641	365	42	Reticulum cell sarcoma						
38	F	56	942	272	911	40	80	M	44	1664+	367	1659+	23
77	M	65	776+	198	743+	14	81	M	65	86	427	86	45
84	F	74	372	37	366	28	Prostate						
90	M	58	163	199	156	31	82	M	48	1306	467	255	77
92	F	60	101	154	99	28	89	M	68	331	944	122	15
99	M	77	20	649	20	33	Uterus						
100	M	38	283	162	274	80	83	F	62	1273	497	86	44
Rectum							Brain						
39	F	56	185	422	62	38	85	M	49	47	296	34	59
40	F	75	479	82	226	10							
41	F	57	875	551	437	62							
42	M	56	115	140	85	13							
43	M	68	362	106	122	36							
44	M	54	244	645	198	80							
45	M	59	2175	407	759	64							

(Continued on following page.)

Table 1. (Continued)

Case	Sex	Age, yr	Survival, days [†]				Case	Sex	Age, yr	Survival days [†]			
			A	B	C	D				A	B	C	D
Pancreas							Chronic lymphatic leukemia						
86	M	77	465	56	342	20	94	F	59	3281	237	889	30
87	M	67	27	60	27	24							
88	F	60	83	99	16	58							

* The + following the survival time of an ascorbate-treated patient indicates that the patient was alive on 15 May 1978.

[†] A, survival time of the ascorbate patient, measured from the date of first hospital attendance for the cancer that reached the terminal stage; B, the corresponding mean survival time of that patient's 10 matched controls; C and D, survival times for ascorbate patient and controls, respectively, measured from the dates of untreatability.

tional periods of survival of the 18 ascorbate patients still alive on 10 August 1976. It is apparent that there is reasonably good agreement with the values reached in our present more detailed study.

Comparison of the survival times of ascorbate-treated cancer patients and their matched controls measured from the date of untreatability is shown for eight of the nine groups in Figs. 1 and 2. The median increase is about 140 days, which is about 50% of the mean increase, the difference being caused by some ascorbate-treated patients with very long survival times, as was discussed in our previous communication (1).

In that earlier paper, the ratio of average survival time after untreatability of the ascorbate-treated group to that of controls was given as 4.2; this value has now increased to 5.6 because of the continuing survival of some of the original patients. The corresponding ratio in the present study is 7.7.

Although the matched controls were selected without consideration of the date of death or whether death had occurred, none was still living at the time when Table 1 was compiled. The explanation of this fact is that cancer patients who reach a terminal stage have a life expectancy of only a few months at most. Nevertheless, it seems worthwhile to compare the controls with the 92 ascorbate-treated patients who had also died when Table 1 was prepared, measuring survival time in both groups from date of first hospital attendance to date of death, the two reference dates that are exactly known. This comparison gives 251 days as the increase in average survival time of the ascorbate-treated subjects over the value for the

controls, compared to 321+ days when all 100 treated subjects are included.

Of the 1000 control patients, 370 were completely concurrent with the ascorbate-treated patients. The mean value of the survival times of these completely concurrent control patients was 327 days measured from the date of first hospital attendance and 42 days measured from the date of untreatability, compared with 379 and 36 days, respectively, for the overlapping and historical controls. The values of the increase in survival time of the ascorbate-treated patients over that for the completely concurrent controls are 354+ days (from date of first hospital attendance) and 257+ days (from date of untreatability); the average is 306+ days. These values, with use of the 370 completely concurrent controls, are a little larger than those with use of all 1000 controls (average 288+ days for the two reference dates). The average of the values for the concurrent controls and all controls, equally weighted, is 297+ days.

Statistical tests show that the survival times of the ascorbate-treated patients are significantly greater than those of their matched controls. The nonparametric Wilcoxon matched-pairs signed-ranks test was carried out for each of the nine groups in Table 2, for both survival time after first hospital attendance and survival time after date of untreatability. Each of the 18 tests led to rejection of the null hypothesis of the same distribution function for survival times of ascorbate-treated patients and of their controls at a highly significant level [P (one-tailed) < 0.01 or 0.001].

Table 2. Differences in average survival times of ascorbate-treated patients and matched controls

Primary tumor type	Patients, no.		Mean survival times, days				Increased survival times of ascorbate-treated patients, days*		
			From first hospital attendance		From date of untreatability		E A - B	F C - D	G
	Test	Controls	Test	Control	Test	Control			
Colon	17	170	458+	316	352+	33	142+	319+	324
Bronchus	17	170	219+	118	186+	31	101+	155+	184+
Stomach	13	130	286+	159	182+	32	127+	150+	134+
Breast	11	110	1396+	1020	487+	52	376+	435+	378+
Kidney	8	80	774+	492	381+	39	282+	342+	348+
Bladder	7	70	1669+	420	355+	21	1249+	334+	226+
Rectum	7	70	634	336	270	43	298	227	247
Ovary	6	60	884	366	183	69	518	114	157
Others	14	140	706+	279	278+	37	427+	241+	189+
All	100	1000	681+	360	293+	38	321+	255+	234+

* E, calculated as A - B; F, calculated as C - D; G, additional survival time of first set of ascorbate-treated patients with first set of controls ref. (1) to 15 May 1978, when seven of them were still living (measured from the date of untreatability). The + following a number indicates that one patient in the group (two in the bladder group) continued to survive after 15 May 1978.

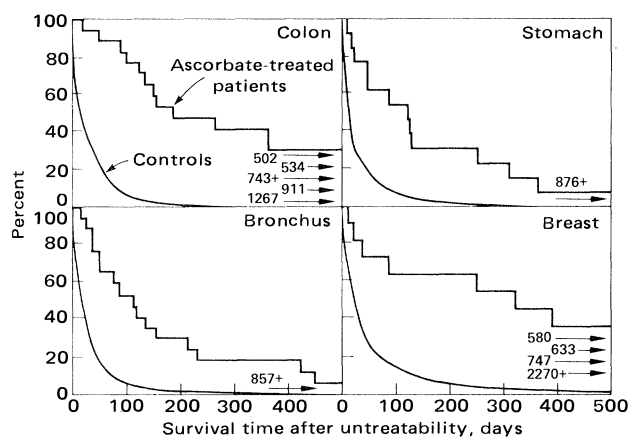


FIG. 1. Fraction of survivors at times after date of onset of terminal stage (untreatability) of ascorbate-treated patients with primary cancer of colon, stomach, bronchus, or breast, compared with that for matched controls (10 per ascorbate-treated patient).

Conclusion

From examination of the case records for a revised set of 100 ascorbate-treated patients with terminal cancer [mostly the same as those reported in our earlier study (1)] and a new set of 1000 matched controls, and using the precisely known date of first hospital attendance and date of death as reference points, we conclude again that there is strong evidence that treatment of patients in Scotland with terminal (untreatable) cancer with about 10 g of ascorbate per day increases their survival significantly (by an average of about 300+ days). Larger amounts might have a greater effect. Eight of the 100 ascorbate-treated patients were still alive on 15 May 1978, even though they had been judged, at the time when administration of ascorbate was initiated, to have reached the terminal stage of their illness; their mean survival time after the date of untreatability is 3.5+ yr. Survival times greater than 1 yr after the date of untreatability were observed for 22 of the 100 ascorbate-treated patients, 55 times the fraction (4/1000) for the matched controls. These 22 ascorbate-treated patients had on 15 May 1978 survived an average of 2.4 yr after reaching the apparently terminal stage.

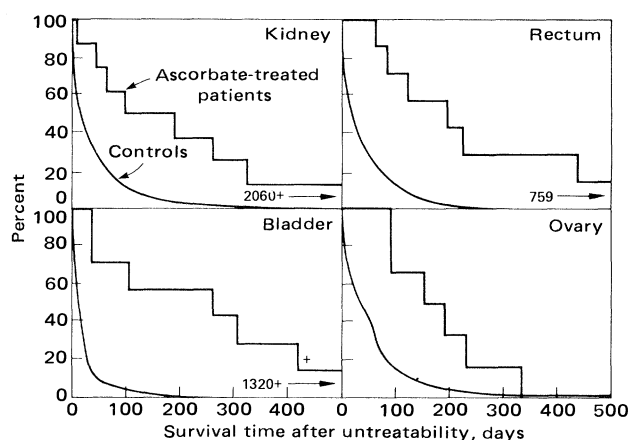


FIG. 2. Fraction of survivors at times after date of onset of terminal stage (untreatability) of ascorbate-treated patients with primary cancer of kidney, rectum, bladder, or ovary, compared with that for matched controls (10 per ascorbate-treated patient).

There is little doubt, in our opinion, that treatment with ascorbate in amounts of 10 g/day or more is of real value in extending the life of patients with advanced cancer. Moreover, as has been pointed out before (2), the quality of life of the patients is improved by the administration of ascorbate. Also, we continue to believe that the addition of ascorbate to treatment regimens at an earlier stage might well have a much greater effect, increasing the average survival time by several years.

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2. Cameron, E. & Campbell, A. (1974) *Chem. Biol. Interact.* **9**, 285-315.