CLINICAL RESEARCH STUDY

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Using Animated Computer-generated Text and Graphics to Depict the Risks and Benefits of Medical Treatment

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ABSTRACT

OBJECTIVE: Conventional print materials for presenting risks and benefits of treatment are often difficult to understand. This study was undertaken to evaluate and compare subjects' understanding and perceptions of risks and benefits presented using animated computerized text and graphics.

METHODS: Adult subjects were randomized to receive identical risk/benefit information regarding taking statins that was presented on an iPad (Apple Corp, Cupertino, Calif) in 1 of 4 different animated formats: text/numbers, pie chart, bar graph, and pictograph. Subjects completed a questionnaire regarding their preferences and perceptions of the message delivery together with their understanding of the information. Health literacy, numeracy, and need for cognition were measured using validated instruments.

RESULTS: There were no differences in subject understanding based on the different formats. However, significantly more subjects preferred graphs (82.5%) compared with text (17.5%, $P < .001$). Specifically, subjects preferred pictographs (32.0%) and bar graphs (31.0%) over pie charts (19.5%) and text (17.5%). Subjects whose preference for message delivery matched their randomly assigned format (preference match) had significantly greater understanding and satisfaction compared with those assigned to something other than their preference.

CONCLUSIONS: Results showed that computer-animated depictions of risks and benefits offer an effective means to describe medical risk/benefit statistics. That understanding and satisfaction were significantly better when the format matched the individual's preference for message delivery is important and reinforces the value of "tailoring" information to the individual's needs and preferences.
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KEYWORDS: Computer animation; Patient comprehension; Patient preferences; Risk/benefit statistics

For patients to make informed decisions regarding healthcare-related treatments, it is important that they understand the information and are able to weigh the relative risks and benefits. This is important given that a lack of understanding may cause patients to misinterpret the risks and benefits, potentially placing them at risk.[1,2] Unfortunately, many individuals have difficulty making tradeoffs between risks and benefits because of a lack of clarity in the presentation of the information and because of poor numeracy (quantitative literacy) abilities.[3,4] Indeed, a lack of ability to understand numbers, fractions, and percentages may deny a patient the ability to quantify risk or place it in context with their own situation. Peters et al[5] showed that innumerate individuals were more likely to base medical decisions on emotion or trust rather than numbers per se.

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Treatment risks and benefits traditionally are articulated by the physician or written as text in a consent document. However, as several studies have demonstrated, these approaches are not uniformly effective.[6,7] The reasons for this are multifactorial, but the common "one size fits all" approach may fail because it neglects the needs of patients with different informational preferences or learning abilities. One approach that has been shown to be effective in improving patients' understanding is to present risks and benefits in graphic format (eg, histograms and pictographs) rather than text.[7-14] Indeed, Tait et al[7] recently showed that risks and benefits presented in tables and pictographs were better understood compared with standard text. However, these studies have focused largely on print formats that convey risks and benefits separately from each other.

CLINICAL SIGNIFICANCE

- Patients' understanding of conventional print materials for presenting risk/benefit information is often poor and can lead to misinterpretation and impaired decision making.
- We evaluated and compared patients' understanding and perceptions of the risks and benefits of taking statins by using animated computer-generated text and graphics.
- Results demonstrate that the use of visually salient animated computer-based media messages offers a novel, effective, and acceptable way of presenting important risk/benefit statistics for medical treatment.

The increasing use and sophistication of computer graphics have added a new dimension to the presentation of medical information. Modern computer graphics provide a unique ability to present scientific information in an easier to understand manner. Technologic advances in computer graphics enable higher-quality visual models that can convey medical information to patients in a coherent way. The incorporation of dynamic visual content has proven effective in several patient education applications, including ankle fracture surgery,[15] intravenous contrast material,[16] and colonoscopy.[17]

Risks and benefits are perhaps the 2 most important elements of consent that subjects require to make an informed decision.[18] However, previous work suggests that risks and benefits are often poorly understood and frequently misinterpreted.[2] Given the increased visual salience of computer images over traditional print media, this study was undertaken to evaluate and compare subjects' preferences for and understanding of risks and benefits presented using animated computerized text and graphics in which risks and benefits are displayed simultaneously.

MATERIALS AND METHODS

This study was approved by the University of Michigan's institutional review board. Adult subjects (patients and family members) were approached in the University of Michigan's Cardiovascular Center's pre-procedure waiting areas, and verbal consent obtained. Subjects were randomized to receive identical information about the risks and benefits of taking statins for hypercholesterolemia presented on an iPad (Apple Corp, Cupertino, Calif) in 1 of 4 different animated formats: text/numbers, pie chart, bar graph, and pictograph. Subjects were informed that we were evaluating the process of giving risk/benefit information but that they would *not* actually be receiving any treatments as part of this research. They were further told that although the information provided was based on real risk/benefit data, they should not consider any of the information relevant to their own healthcare and that their responses would have *no* implications for any treatment decisions. Although the iPad program was intuitive, an assistant was available to help as necessary.

Program Development

The initial content for the risk/benefit graphics was based on the extant literature, expert opinion, and our own research. Graphic designers prepared prototypes of the risk/benefit graphics that were then reviewed by both expert and lay individuals for content and flow. This process involved several iterations before deployment. The information was presented on an iPad and began with a common introduction and narrative (voiceover) regarding the use of statins for reducing cardiac events in patients with hypercholesterolemia. We chose statins specifically because we thought that most subjects would be familiar with their use. Subjects were then randomized to 1 of the 4 different message formats each accompanied by a common narrative. Both text and graphic formats were presented in color with action elements to highlight the specific risk/benefit statistics. In addition, all text was written at the seventh- to eighth-grade reading level. Screenshots of the text and graphic formats are shown in **Figures 1** to **4**. The voiceover

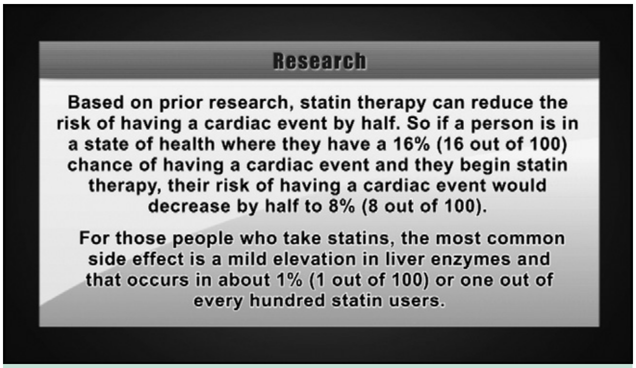

Figure 1 Screenshot of the text format.

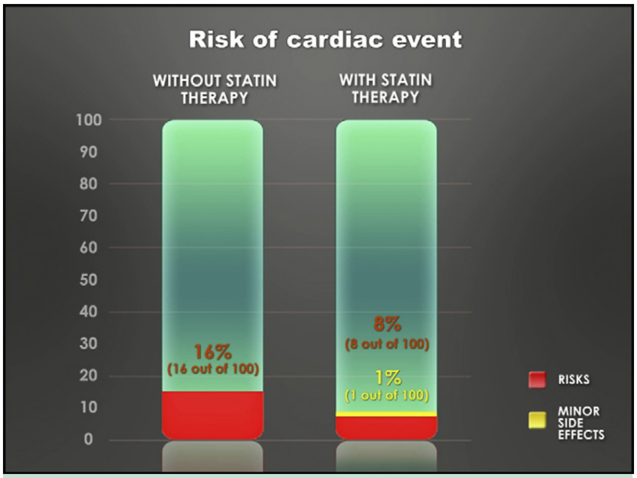

Figure 2 Screenshot of the bar graph.

was identical for all risk/benefit information, regardless of the format.

Understanding and Preferences

Having reviewed the information, subjects were asked to complete a questionnaire to establish their understanding of the risks and benefits of taking statins. Items addressed both *gist* (essential) and *verbatim* (actual) understanding of the risk/benefit statistics. For example, one item addressing gist understanding asked "Among patients who take statins for high cholesterol, which of the following is most likely: (1) experiencing a cardiac event, (2) experiencing an increase in liver enzymes, (3) both are equally likely, and (4) don't know." One item related to verbatim understanding asked "If 100 patients with high cholesterol take statins, how many would likely experience a cardiac event?" Composite measures of understanding based on the number of correct responses to the gist and verbatim questions (of 6) were calculated.

Subjects also were asked several questions related to their perceptions of the message delivery to which they were randomized. For example, subjects were asked their perceptions of how "effective," "easy," "helpful," and "trustworthy," the format was on their understanding of the risks and benefits. Responses were recorded on 0 to 10 interval scales, where 10 = the maximum response (eg, "extremely effective"). At the end, subjects were shown all 4 risk/benefit formats and asked which they preferred and why.

Subject Characteristics

Sociodemographic variables, including age, gender, racial/ethnic background, education, and family income, were recorded. In addition, health literacy was measured using the Rapid Estimate of Adult Literacy in Medicine instrument.[19] Numeracy also was measured using the validated Subjective Numeracy Scale,[20,21] which assesses the ability to work with numbers. Finally, subjects completed the need for cognition (NFC) instrument, which measures an individual's tendency to engage in effortful thinking.[22,23] Subjects also were asked whether they were currently taking statins.

Statistical Analysis

Statistical analyses were performed using PASW software (v 18.0, PASW Inc, Chicago, Ill). Sample size determination was based on preliminary data describing subjects' understanding of risks presented in different formats. On the basis of these data, we required a sample size of 49/group ($\alpha = 0.05$, $\beta = 0.10$, 2-tailed, N = 196) to detect clinically important differences in understanding. Comparisons of parametric data between groups were analyzed using analysis of variance with post hoc testing. Nonparametric data were analyzed using Mann-Whitney *U*, chi-square, and Fisher exact tests, as appropriate. A multiple linear regression model also was conducted to examine predictors of understanding. Collinearity diagnostics revealed tolerance values of 0.886 to 0.985 and variable inflation factors of 1.015 to 1.128 confirming the relevance of the retained factors. Data are expressed as percentages and mean ± standard deviation. Significance was accepted as $P < .05$ or $P < .016$ for multiple comparisons (Bonferroni).

RESULTS

A total of 320 adult subjects were approached to participate, of whom 65 declined participation. Only 1 subject declined because of the iPad. In addition, the first 55 subjects were excluded because of a misunderstanding of 2 of the verbatim questions. These items were reworded, and analysis therefore includes data from the subsequent 200 subjects who consented.

Table 1 describes the demographics of each format group. As shown, there were no differences between groups. Table 2 compares overall understanding (gist and verbatim) of the risk/benefit statistics among groups by literacy, numeracy, NFC, and education. Of note, bar graphs were the only format that showed significant differences in under-

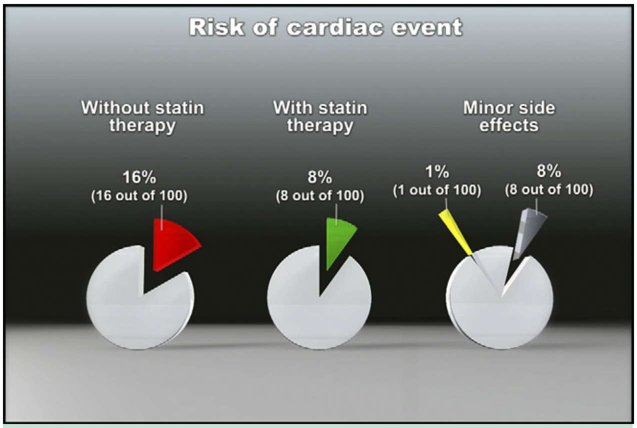

Figure 3 Screenshot of the pie chart.

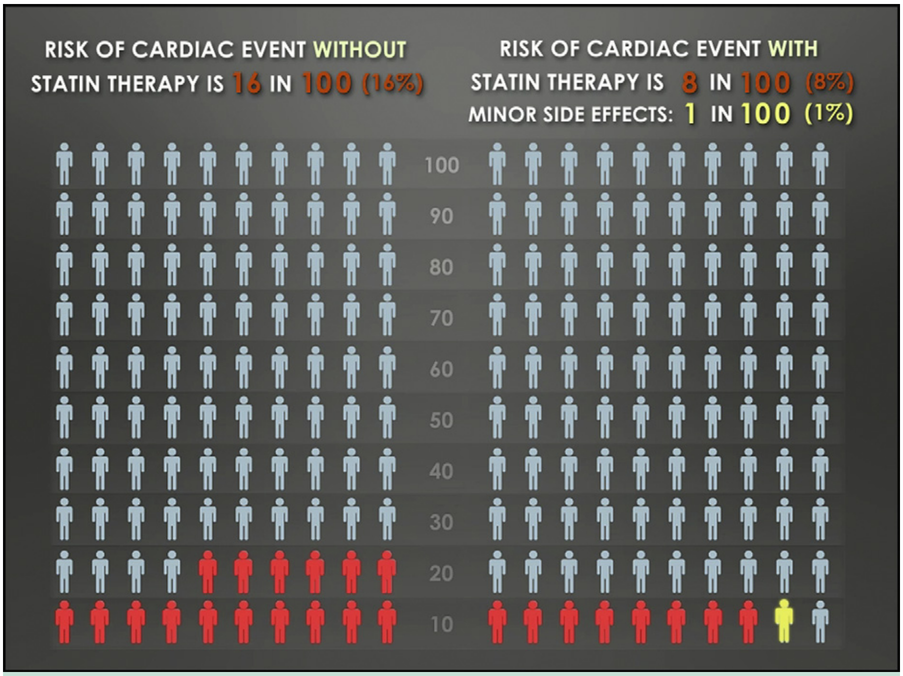

Figure 4 Screenshot of the pictograph.

standing between individuals with high and low numeracy, literacy, education, and NFC. There also were no differences in understanding by age (<65 vs ≥65 years) and between subjects who were currently taking statins compared with those who were not. Subjects had no difficulties using the program.

When shown all 4 formats, 64 subjects (32.0%) stated that they preferred pictographs, 62 subjects (31.0%) stated that they preferred bar graphs, 39 subjects (19.5%) stated that they preferred pie charts, and 35 subjects (17.5%) stated that they preferred text. Of those who received text information, only 5 (10%) stated that they actually preferred text. Only 3 subjects (6%) who received the pie chart actually preferred the pie chart, 8 subjects (16%) who were assigned to the bar graph preferred the bar graph, and 12 subjects (24%) who were assigned to the pictograph preferred the pictograph.

Table 1 Demographics

	Text n = 50	Pie Chart n = 50	Bar Graph n = 50	Pictograph n = 50
Age (y)	55.1 ± 12.4	52.1 ± 15.2	55.2 ± 14.7	53.6 ± 12.9
Gender (M/F %)	50/50	38/62	52/48	46/54
Current stain use	16 (33.3)	12 (24.0)	11 (22.0)	12 (24.0)
Race/ethnicity				
White	43 (89.6)	46 (92.0)	44 (88.0)	40 (80.0)
African American	2 (4.2)	4 (8.0)	3 (6.0)	3 (6.0)
Hispanic	1 (2.2)	0 (0.0)	(0.0)	3 (6.0)
Highest education				
High school or less	13 (27.1)	12 (24.0)	8 (16.0)	9 (18.4)
Some college	10 (20.8)	15 (30.0)	18 (36.0)	13 (26.5)
Undergraduate or higher	25 (52.1)	23 (46.0)	24 (48.0)	27 (55.0)
Numeracy* (median)	42	39	38	40
Literacy† (median)	65	65.5	66	65
NFC‡ (median)	22	22	22	22

NFC = need for cognition.
Data are presented as n (%), mean ± standard deviation (SD), and median.
*Numeracy, 0-48 scale.
†Literacy, 0-66 scale.
‡NFC, 1-35 scale (higher scores reflect higher attributes).

Table 2 Subjects' Understanding of Risks and Benefits by Message Format

	Text n = 50	Pie Chart n = 50	Bar Graph n = 50	Pictograph n = 50
No. of correct questions (range, 0-6)	2.90 ± 1.2	2.44 ± 1.2	2.86 ± 1.3	2.80 ± 1.3
By numeracy				
High (R)	3.06 ± 1.2	2.55 ± 1.3	3.37 ± 1.9	3.06 ± 1.3
Low	2.50 ± 1.0	2.26 ± 1.1	1.94 ± 0.9*	2.29 ± 1.2*
By literacy				
High (R)	2.89 ± 1.1	2.48 ± 1.2	3.00 ± 1.2	2.91 ± 1.3
Low	3.00 ± 2.8	1.50 ± 0.7	1.25 ± 0.9*	2.00 ± 1.1
By NFC				
High (R)	3.00 ± 1.3	2.34 ± 1.3	3.18 ± 1.2	2.91 ± 1.3
Low	2.79 ± 1.1	2.54 ± 1.1	2.45 ± 1.3*	2.64 ± 1.5
By highest education				
Less than college (R)	2.56 ± 0.9	2.33 ± 1.3	2.42 ± 1.2	2.05 ± 0.9
College graduate or higher	3.24 ± 1.2	2.56 ± 1.04	3.33 ± 1.2*	3.44 ± 1.3

NFC = need for cognition; R = reference group (*$P < .05$ vs reference group).

Data are presented as the mean ± SD of number of correct questions (range, 0-6).

Low numeracy = 0-35, high numeracy = 36-48 on the Subjective Numeracy Scale. Low literacy = 0-60 (third- to eighth-grade equivalence), high literacy = >61 (ninth-grade equivalence or higher). Low NFC = 0-21, high NFC = >21, cutoff based on median split.

Overall, graphs were preferred to text (82.5% vs 17.5%, $P < .001$). This difference was consistent among subjects with both low and high numeracy, education, age, and NFC. Men were significantly more likely to prefer graphs than were women (89.1% vs 76.4%, $P = .019$). Of note, despite a stated preference for graphs, text was deemed more "effective" in presenting risk/benefit statistics (8.5 ± 1.5 vs 7.75 ± 2.2 of 10, $P = .007$), "clearer" to understand (8.82 ± 1.5 vs 8.1 ± 1.9, $P = .004$), and more "scientific" (7.82 ± 1.8 vs 6.7 ± 2.5, $P = .001$).

Significantly more subjects stated they would prefer to receive medical information on a computer or tablet device (52.0%) compared with conventional print media (39.4%, $P = .012$). Furthermore, 174 subjects (87.0%) also stated that they liked to receive supplemental verbal information about risks and benefits. Indeed, the accompanying narrative was deemed "helpful," scoring 7.72 ± 2.3 of 10 (10 = extremely helpful). Older subjects (≥52 years, based on median split) found the narrative to be significantly more "helpful" than younger subjects (8.16 ± 1.9 vs 7.17 ± 2.6 of 10, $P = .003$). Likewise, minority subjects found the narrative more "helpful" than white subjects (8.85 ± 1.5 vs 7.61 ± 2.3, $P = .003$).

Of note, subjects whose preferred message format matched their randomly assigned format (preference match) had significantly greater understanding and satisfaction compared with those who were assigned to something other than their preference (**Table 3**). Of those with a preference match, 42.9% matched with pictographs, 28.6% matched with bar graphs, 17.9% matched with text, and 10.7% matched with pie charts. Factors found to be significantly associated with understanding by univariate analysis were entered into a regression model, that is, age, literacy, numeracy, education (high school vs college), family income, and preference match. Results identified several independent predictors of understanding, including higher numeracy, higher literacy, college education, and preference match (**Table 4**).

DISCUSSION

The results of this study showed that there were no differences in subject understanding of risk/benefit information presented using different animated computer-based text and graphic formats. These results differ from some studies that suggest that graphic formats, particularly pictographs, are more effective than text in promoting understanding of risk/benefit information.[3,7] Hawley et al[12] recently surveyed subjects to assess their understanding and perceptions of 6

Table 3 Relationship Between Preference Match* and Subjects' Understanding, Satisfaction, and Perceptions

	No Match n = 172	Match n = 28
Understanding‡	2.67 ± 1.2	3.21 ± 1.2†
Satisfaction§	7.76 ± 2.2	8.50 ± 1.6†
Effectiveness in depicting risk/benefit§	7.78 ± 2.1	8.89 ± 1.4†
Helpful in depicting risk/benefit§	7.86 ± 2.2	8.61 ± 1.5†
Easy to determine risk/benefit§	8.01 ± 2.0	8.79 ± 1.6†
Clarity of risk/benefit information§	8.14 ± 1.9	8.89 ± 1.1†

Data are presented as mean ± SD.

*Subjects' preference for message delivery matched their random assignment.

†$P < .05$ vs no match.

‡Number of correct responses of 6.

§Scale of 0 to 10, where 10 = maximum response.

Table 4 Independent Predictors of Understanding

	B	SE	P
College graduate	0.677	0.16	.000
High numeracy*	0.046	0.01	.000
High literacy†	0.041	0.02	.024
Preference match‡	0.636	0.24	.010

SE = standard error.
*High numeracy = 36-48 on the Subjective Numeracy Scale.
†High literacy = ≥ 66 on the Rapid Estimate of Adult Literacy in Medicine test.
‡Format assignment matched format preference.

different graphic formats for presenting cardiac disease statistics. Results showed that pictographs resulted in more accurate gist and verbatim knowledge compared with other graphic formats; however, there were no comparisons with standard numeric text. We recently demonstrated that pictographs were superior to text in providing better understanding among both numerate and innumerate individuals.[3,7] Other studies support these findings suggesting that graphs may require less cognitive effort and are thus more effective in presenting quantitative risk information.[9,12,13,24-26] In our study, however, text was shown to be equally as effective as graphs in helping subjects understand the risk/benefit statistics. The reason for this is unclear, although in the previous studies, the text was presented in a static print format that lacked an accompanying narrative and the visual salience of our computer-generated animated text messages. In the current study, the text was written with high "processability," that is, large font, bolding, and brief message. Text with high processability has been shown to improve adults' and children's understanding of consent/assent information.[27-29] In addition, the text incorporated action effects that provided a more dynamic message and, as such, may have approached the visual salience of the graphic formats. In addition, all formats were accompanied by a standard voiceover that was perceived as "very helpful" by a majority of subjects and that may have facilitated a common understanding of the material.

Compared with standard print text, visual presentations of risks and benefits have been shown to reveal patterns that otherwise may go undetected, better hold an individual's attention, and improve processing of mathematic operations.[30,31] Furthermore, pictures drive conceptual processing, which aids in information retention.[32] Indeed, the concept that "a picture is worth a thousand words" is not merely a cliché but a function of the so-called pictorial superiority effect,[33] which suggests that people are more likely to remember concrete items when presented in a visually salient format.[34,35] The pictorial superiority effect has been established in both children and adults[33,36,37] and thus may have important implications for presenting medical information.

Despite the fact that there were no differences in understanding between groups, subjects preferred the use of graphs, particularly pictographs and bar graphs, over text in reporting risk/benefit statistics. Conversely, however, subjects found text to be more "scientific," "effective," and "clearer" in presenting risk/benefit statistics compared with graphs. The reason for this is unclear but may simply reflect the fact that text presentations of risk/benefit information may be more familiar to the average individual compared with graphs. Alternatively, we only asked this question in relation to the format that they had received. It may be that given a choice between the formats, as we did when asking questions about their preferences, that we would have had received different responses.

Of interest was the observation that understanding and satisfaction were significantly greater when the format assignment happened to match the individual's preference for message delivery. This is important and reinforces the value of "tailoring" information to the individual's preferences. Indeed, several studies have clearly demonstrated that information tailored to the characteristics and information needs of the individual is effective in promoting understanding and positive health-related changes, including smoking cessation, mammography screening, and dietary fat reduction.[38-44] Furthermore, tailored information is more likely to be read and remembered compared with untailored information.[45] Under Petty and Cacioppo's "Elaboration Likelihood Model,"[45] personally relevant information is more likely to be considered and retained. Tailoring has been shown to be particularly effective in presenting understandable health information among minority and educationally disadvantaged groups.[38,40,41] Our results suggest that tailoring also may be an effective means to present important risk/benefit information.

That numeracy and literacy were identified as independent predictors of understanding was not surprising given that many individuals have difficulty with basic reading skills and in understanding basic mathematic concepts.[4,46,47] Our results are in concert with others and important given that individuals with poor numeracy or literacy skills are less likely to understand medical information and more likely to misinterpret risk/benefit statistics.[2] In our study, although low numerate and literate individuals had poorer understanding of the risk/benefit information compared with highly numerate and literate individuals, these differences for the most part were not significant. This suggests that computer-based media formats may be helpful in "closing the gap" between individuals with low and high literacy and numeracy skills.

Study Limitations

Limitations of the study are recognized. First, this study simulated a healthcare setting, that is, subjects were not real patients receiving information about personal statin use. Although this approach may limit the ability to generalize beyond the experimental setting, there is considerable evidence to show that behaviors based on real and simulated situations are highly correlated.[48,49] Second, we did not compare the computer graphics with standard paper-based formats. However, previous work has shown that a computer-based program for cardiac catheterization was better understood compared with print information.[50] Finally, we focused on understanding of only 2 components of the consent process (risks/benefits) presented in a relatively simple and concise format. Perhaps the effect of different formats may be more delineated when presenting more comprehensive information.

CONCLUSIONS

The results of this study suggest that visually salient animated computer-based media messages offer a novel, effective, and acceptable way of presenting important risk/benefit statistics regarding medical treatments. Furthermore, this research highlights and reinforces the importance of "tailoring" information to the preferences and informational needs of the individual. As healthcare moves further away from traditional paper charts and medical information, computer-based media offer a promising approach to enhancing the communication of health-related information.

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