

1 **Influence of provider recommendations to restart vaccines after childhood cancer on caregiver**
2 **intention to vaccinate¹**

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Abbreviations	
CI	Confidence Interval
COG	Children’s Oncology Group
IDSA	Infectious Disease Society of America
HPV	Human Papillomavirus
PCH	Primary Children’s Hospital
PCP	Primary Care Provider
RR	Relative Risk

28

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29 **Abstract**

30 **Purpose:** We studied the influence of oncology and primary care provider (PCP) recommendations on
31 caregiver intentions to restart vaccines (e.g., catch-up or boosters) after cancer treatment.

32 **Methods:** We surveyed primary caregivers ages 18 or older with a child who had completed cancer
33 treatment 3-36 months prior (N=145) about demographics, child's vaccination status, and healthcare
34 factors (e.g., provider recommendations, barriers, preferences for vaccination). We compared these
35 factors by caregiver's intention to restart vaccines ("vaccine intention" vs. "no intent to vaccinate") using
36 bivariate and multivariable analyses.

37 **Results:** Caregivers were primarily ages 30-39 years (54.9%), mothers (80.6%), college graduates
38 (44.4%), Non-Hispanic (89.2%), and married (88.2%). Overall, 34.5% of caregivers did not know which
39 vaccines their child needed. However, 65.5% of caregivers reported vaccine intention. Fewer caregivers
40 with no intention to vaccinate believed vaccinating their child helps protect others (85.4% vs. 99.0%,
41 $p<0.01$), that vaccines are needed when diseases are rare (83.7% vs. 100.0%, $p<0.01$), and that vaccines
42 are safe (80.4% vs. 92.6%, $p=0.03$) and effective (91.5% vs. 98.9%, $p=0.04$) compared to vaccine
43 intention caregivers, respectively. Provider recommendations increased caregivers' likelihood of vaccine
44 intention (oncologist: RR=1.65, 95% CI 1.27-2.12, $p<0.01$; PCP: RR=1.51, 95% CI 1.19-1.94, $p<0.01$).

45 **Conclusions:** Provider recommendations positively influence caregivers' intention to restart vaccines
46 after childhood cancer. Guidelines are needed to support providers in making tailored vaccine
47 recommendations.

48 **Implications for Cancer Survivors:** Timely vaccination after childhood cancer protects patients against
49 vaccine-preventable diseases during survivorship. Caregivers may benefit from discussing restarting
50 vaccinations after cancer with healthcare providers.

51 **Key Words:** immunization, childhood, survivorship care, provider recommendation, caregiver

52 **Introduction**

53 Childhood immunization is one of the greatest public health advancements in the last century. Overall,
54 31% of pediatric cancers occur in children under age five, an age range during which the majority of
55 childhood vaccines are recommended [1]. Recommendations for vaccination continue throughout
56 adolescence and teenage years [1]. Guidelines generally suggest that most children with cancer begin to
57 receive routine or catch-up vaccines once immunological recovery is complete, approximately 3-6 months
58 following the completion of chemotherapy depending on the type of treatment administered,
59 immunological recovery, and type of vaccine (attenuated vs. non-attenuated) [2-4]. Recent research
60 suggests that among survivors who have not undergone bone marrow transplantation, receipt of
61 attenuated vaccines as early as three months after treatment might result in protective antibody responses
62 [5]. However, this research is based on small samples of patients in a limited age range. The lack of
63 consensus regarding the optimal approach to and timing of vaccination after childhood cancer treatment
64 remains a challenge for caregivers and clinicians alike.

65 While studies suggest that immunity typically can be restored successfully after cancer treatment [5-7],
66 caregivers of childhood cancer survivors may be skeptical about the safety of vaccines for their child [8].
67 At the same time, some childhood cancer survivors may not see a primary care provider (PCP) in the
68 initial years after their cancer treatment ends [3, 9], which may interrupt their access to vaccinations. Yet,
69 there have been few studies on immunization practices of childhood cancer survivors. There is evidence
70 that adult survivors of childhood cancer forego receipt of the yearly influenza vaccine [10], and a growing
71 number of studies report survivors have a low uptake of the human papillomavirus (HPV) vaccine [11-
72 13]. This limited evidence is concerning as survivors' compromised immune systems during, and
73 potentially after, treatment puts them at risk for contracting vaccine-preventable infections, including
74 those that can increase cancer risk, such as HPV and Hepatitis B [14].

75 An emphatic recommendation from a healthcare provider is an important factor in improving vaccine
76 intentions among caregivers in the general population [15, 16]. Whether this holds true for caregivers of
77 children who have undergone cancer treatment remains unknown. In this study, we report findings from a
78 clinic-based survey of primary caregivers of childhood cancer survivors. Caregivers were surveyed about
79 their intention to restart vaccines after their child's cancer treatment, their vaccine beliefs, and their
80 vaccine experiences. Our goal was to determine whether intent to restart vaccines after treatment was
81 greater among caregivers who had received a recommendation about vaccinations after cancer from their
82 child's provider. A secondary goal of this study was to explore caregivers' hesitancy and barriers to
83 restarting vaccines.

84 **Methods**

85 This study was part of a larger project on vaccination after pediatric cancer at Intermountain Healthcare's
86 Primary Children's Hospital (PCH). PCH is part of the Children's Oncology Group and is the only
87 pediatric oncology clinic in Utah, providing oncology care to the five state Mountain West region (Utah,
88 Nevada, Idaho, Wyoming, and Montana). The University of Utah and Intermountain Healthcare's
89 institutional review boards approved this study. The data are available from the corresponding author
90 upon reasonable request.

91 *Participants*

92 Eligible participants included English-speaking caregivers ages 18 and older. Eligible caregivers had a
93 child diagnosed with cancer at ages 17 or younger and had completed cancer treatment at PCH between
94 3-36 months prior. This timeframe was selected because most survivors return to oncology clinics for
95 regular follow-up care during this period. We identified eligible patients through chart review.

96 *Procedures*

97 Participants could complete the survey one of two ways. Caregivers whose child had a scheduled
98 appointment were approached in person at PCH from October 2017-December 2018, or were

99 mailed/mailed a survey if they did not have a clinic visit scheduled in this timeframe. At this point,
100 eligible caregivers completed the informed consent process and were enrolled in the study. To minimize
101 misinterpretation of survey questions, a member of the research team was available either in-person or
102 over the phone to guide caregivers in completing the survey and an information sheet with vaccine names
103 and definitions was provided.

104 Survey data was collected and stored electronically in REDCap; hard copies were input into REDCap.
105 Participants received a \$20 gift card.

106 *Survey Design*

107 The survey was designed based on a literature review and input from experts in childhood vaccinations,
108 including a pediatric infectious disease specialist and two pediatric oncologists (one with a focus in
109 cancer survivorship). We pilot tested the survey with seven caregivers of pediatric cancer survivors in a
110 focus group. Prior to the focus group, caregivers received the survey then discussed their notes and
111 questions about the survey as a group. Using both the provider and focus group feedback, we revised the
112 survey and obtained expert feedback from a health educator, pediatric oncologists, and PCPs to finalize
113 the items. The final survey included 65-items with the following domains: vaccine experiences before and
114 after cancer, vaccine preferences, caregiver demographics, childhood cancer survivor demographics, and
115 cancer factors. Before completing the survey, caregivers were provided terms that included a list of all
116 recommended vaccines, including the yearly influenza vaccine, and the recommended age for each
117 vaccine, and definitions of other terms (i.e., cancer treatment, catch-up vaccines, booster vaccine, titer
118 testing, and primary care provider). Results from questions on HPV vaccination are reported elsewhere
119 [17].

120 *Survey Domains*

121 *Intention to restart vaccinations outcome*

122 Our primary outcome was intention to restart vaccinations after cancer (“vaccine intention” vs. “no intent
123 to vaccinate”). We created this outcome using two survey questions: “Has your child received any
124 vaccinations *after* completing cancer treatment?” and “Do you plan on having your child receive vaccines
125 they missed during cancer treatment?”

126 Caregivers were categorized as “vaccine intention” if they planned on having their child receive vaccines
127 they missed during cancer treatment and/or their child had already restarted getting vaccines. Caregivers
128 were categorized as “no intent to vaccinate” if they did not plan on having their child receive vaccines
129 missed during treatment, if they did not know whether their child needed catch-up/booster vaccines, or if
130 they indicated that their child did not need catch up/booster vaccines. We re-categorized eight participants
131 to “restart vaccines” who responded that their child did not need catch up/booster vaccines because their
132 child had received at least one vaccine after completing cancer treatment in a separate question.

133 *Other Measures*

134 *Caregiver demographics*

135 Caregiver demographics included self-report for age, relationship with the survivor, gender, education,
136 race, ethnicity, annual household income, insurance status, and marital status. We defined rurality of
137 residence using Rural Urban Commuting Area codes, which are based on population density, commuting
138 time, and urbanization in U.S. census tracts [18].

139 *Childhood cancer survivors’ demographics and cancer factors*

140 Survivor demographic factors included child’s current age, gender, race, ethnicity, insurance status, age at
141 diagnosis, time since diagnosis, and diagnosis.

142 *Healthcare and vaccination factors*

143 Caregivers indicated whether they had received a provider recommendation for catch-up/booster vaccines
144 from their child’s oncologist/cancer care team (yes/no) or from a PCP (yes/no). Participants also reported

145 whether their oncologist/cancer care team had discussed when to restart their child's vaccine schedule
146 (yes/no/my child did not need catch-up) and whether their child has a PCP (yes/no/don't know) and
147 whether their child had visited a PCP since completing treatment (yes/no). Finally, participants indicated
148 perceived barriers to completing vaccinations after cancer treatment (9 items about distance, time,
149 transportation, scheduling, cost, knowledge) and their vaccine preferences (11 items about vaccine
150 importance, safety, efficacy, immunity, provider discussions about vaccines, side-effects). Barriers to
151 completing vaccinations included an open-ended "Other" item.

152 *Statistical analysis*

153 We calculated summary statistics for caregiver demographic and their child's demographic and cancer
154 factors, and compared these factors by intention to restart vaccinations using chi-square tests and Fisher
155 exact tests (for variables with cell sizes $n \leq 5$). A similar approach was used for the healthcare and
156 vaccination factors. Then, to investigate factors associated with intention to restart vaccines, we fit two
157 generalized linear models to estimate relative risks (RR) and assess the relationship of a provider
158 recommendation from either an oncologist/cancer care team (Model 1) or a PCP (Model 2) with
159 caregiver's intention to restart vaccines. We chose to fit separate models for oncologists and PCPs
160 because many pediatric oncology patients do not immediately return to primary care settings upon
161 completion of their cancer treatment, and thus may not have had an opportunity to see a PCP or receive
162 their recommendation for restarting vaccinations.

163 We applied a stepwise forward variable selection to build the final regression models, including only
164 variables that demonstrated significant contributions to explaining variation in vaccine intentions, which
165 included child's current age and time since diagnosis. For the regression analyses, we performed
166 sensitivity analyses removing $n=33$ caregivers who indicated that their child did not need catch up or
167 booster vaccines. We also modeled the regressions without caregivers of patients who had received bone
168 marrow transplant (BMT, $n=8$). Last, we separately ran the regressions excluding caregivers ($n=20$)
169 whose child had not seen a PCP since their cancer diagnosis, but this did not appreciably change the

170 effect estimates and these results are not shown. Missing values were excluded from the analyses.
171 Statistical analyses were performed in Stata 14.2 and statistical significance was set at $p < 0.05$.
172 For “Other” write-in responses related to barriers to vaccination and changes in vaccine beliefs after
173 cancer, we categorized these into common areas. Relevant quotes were extracted to describe additional
174 context to these topics. We compared open-ended responses about barriers to completing vaccinations and
175 changes in vaccine beliefs among caregivers with vaccine intentions and those with no intent to vaccinate.

176 **Results**

177 *Caregiver demographics and vaccinations after cancer*

178 Of 196 caregivers approached in clinic, 143 were consented and completed self-administered
179 surveys (participation rate=72.9%). We also emailed or mailed surveys to caregivers who were unable to
180 complete the survey in clinic or who did not have an appointment scheduled during the study timeframe.
181 Of the 50 caregivers mailed a survey, 10 completed surveys for a mail participation rate of 20%. Of the
182 153 completed surveys, we later found that 8 participants were ineligible, which left 145 completed
183 surveys for analysis. Among the analytic sample, 65.5% reported intention to restart vaccines, whereas
184 34.4% did not (Table 1). The majority of caregivers were ages 30-39 years (54.9%), mothers (80.6%),
185 college graduates (44.4%), married (88.2%), and Non-Hispanic (89.2%). Most caregivers reported annual
186 household incomes of less than \$79,999 (56%). The majority had health insurance (93.7%) and lived in
187 urban locations (81.2%).
188 Of caregivers, 50.3% reported their child had received at least one vaccination after cancer treatment (not
189 shown in table). Among those who said no, 9.9% reported that they did not plan on having their child
190 receive vaccines they missed during cancer treatment, 16.9% stated they did not know if their child
191 required vaccines, 35.2% reported that their child did not need any vaccines, and 38.0% stated that they
192 did plan on having their child vaccinated. In Table 1, caregivers reporting vaccine intention tended to be
193 younger compared to those with no intent to vaccinate ($p=0.03$).

194 *Cancer survivor demographics*

195 In Table 2, most survivors were currently 5-9 years old (35.9%), male (51.0%), Non-Hispanic (85.7%),
196 and insured (97.9%). Over one-third of survivors were diagnosed ages 0-4 years (36.6%), between 3
197 months to <1 year previously (53.8%), and with leukemia (37.2%). There was a higher proportion of
198 caregivers with children ages 15-20 years at the time of survey, with no vaccine intention (36.0%)
199 compared to those with intent to vaccinate (13.7%, $p=0.01$). More caregivers with intent to vaccinate had
200 a child ages 0-4 years at diagnosis (47.4%) compared to those with no vaccine intention (16.0%, $p<0.01$),
201 and a higher proportion of caregivers with vaccine intention were more than a year from diagnosis
202 ($p=0.03$).

203 *Healthcare provider recommendation for catch-up/booster vaccines*

204 In Table 3, caregivers who received a recommendation from an oncologist/cancer care team (62.0% vs.
205 38.0%, $p<0.01$) or PCP (52.3% vs. 47.7%, $p<0.01$) were more likely to report vaccine intention than those
206 who had not received a recommendation. Likewise, 65.2% of caregivers with vaccine intention had
207 discussed when to restart a vaccine schedule with their oncologist/cancer care team compared to only
208 17.0% of caregivers with no intent to vaccinate ($p<0.01$).

209 *Barriers to restarting vaccination after cancer*

210 The most common barrier for caregivers restarting vaccines was not knowing which vaccines their child
211 needed – and this was the case for caregivers with vaccine intention (31.6%) and those with no intent to
212 vaccinate (40.0%, $p=0.31$, Table 3). Less than 10% of caregivers in either group reported barriers related
213 to distance, time, scheduling, transportation, and cost.

214 For those who reported “Other” barriers ($n=29$), we organized write-in responses into five categories: 1)
215 concerns about safety/side effects/causing child pain, 2) concerns about vaccines causing cancer, 3)
216 concerns about child’s immune system not being strong enough for vaccines after treatment, 4) unclear
217 whether their child needs vaccinations, and 5) needing information about which vaccines to get. Parents

218 reporting vaccine intention were most commonly concerned about their child's immune system. One
219 caregiver commented, *"I am a little nervous getting vaccines after chemo wiped his body out."*
220 Caregivers reporting no intent to vaccinate commonly worried about safety/side effects. Some perceived a
221 link between vaccines and cancer, saying, *"I feel as though vaccines may have been [a] partial cause of*
222 *my son's brain cancer."* Multiple caregivers wanted to restart vaccinations, but needed more information,
223 including one caregiver who said, *"We don't always understand everything about the vaccines...I wish*
224 *there was more information prior to vaccine day."*

225 *Vaccine preferences*

226 Caregivers were asked about their general preferences regarding vaccination. More caregivers reporting
227 vaccine intention believed that vaccinating their children helps protect others (99.0% vs. 85.4%, $p<0.01$),
228 and that vaccines are needed even when diseases are rare (100.0% vs. 83.7%, $p<0.01$) compared to those
229 with intent to vaccinate. More caregivers reporting vaccine intention felt that vaccines are safe (92.6% vs.
230 80.4%, $p=0.03$) and effective (98.9% vs. 91.5%, $p=0.04$) compared to those with no intent to vaccinate.
231 There were no other statistically significant differences by intention to restart vaccinations for other
232 vaccine preferences. However, we did see differences in experiences when we examined write-in
233 responses from the 22 caregivers who reported their views on vaccines had changed since their child's
234 diagnosis ($n=2$ participants skipped the write-in response). Caregivers were split, with $n=13$ reporting
235 they were more supportive of vaccination after diagnosis and $n=9$ reporting they were less supportive of
236 vaccination after diagnosis. Caregivers who were supportive made comments like *"I used to be [against]*
237 *some [vaccines] but now I agree with them"* and *"[Vaccines] are so important for people around*
238 *immune deficiency kids to be vaccinated so they aren't spreading diseases."* In contrast, caregivers who
239 were less supportive of vaccinations after their child's diagnosis commented *"We are much more*
240 *cautious, we [worry] about so many chemicals that have been in the body"*, *"I worry that they [vaccines]*
241 *change the body in a negative way and could have been part of the cause of cancer"*, and *"Just more*

242 *aware of what is administered to my child. Now I rethink and research much more than I used to. I'm on*
243 *the fence about vaccinations."*

244

245 *Factors associated with intention to vaccinate*

246 In multivariable models (Table 4), caregivers who received a recommendation for catch-up or booster
247 vaccines from their oncologist/cancer care team were more likely report vaccine intention than those
248 without a recommendation (Model 1: RR=1.65, 95%CI 1.27-2.12, p<0.01). Caregivers who had received
249 a recommendation from a PCP were more likely to report vaccine intention than those who had not
250 (Model 2: RR=1.51, 95%CI 1.19-1.94, p<0.01). Vaccine intention decreased with increasing child's age
251 for both models (Model 1: RR=0.97, 95%CI 0.95-0.99, p=0.01; Model 2: RR=0.97 95%CI 0.94-1.00,
252 p=0.04). Greater time since diagnosis was positively associated with vaccine intention (Model 1:
253 RR=1.22, 95%CI 1.04-1.44, p=0.02; Model 2: RR=1.24, 95%CI 1.04-1.46, p=0.01).

254 We performed several sensitivity analyses. First, we re-ran models removing caregivers who believed
255 their child did not need catch up/booster vaccines. In these models, provider recommendations were still
256 strongly associated with vaccine intention (Oncology: RR 1.35, 95%CI 1.06-1.73, p=0.01; PCP:
257 RR=1.28, 95%CI 1.01-1.61, p=0.04). However, the influence of child's age was no longer significant in
258 either model.

259 As recommendations about timing for vaccines after a BMT differ, we did additional analyses to
260 investigate differences with these caregivers. Although there were only 8 patients receiving a BMT in our
261 sample, 85.7% of these caregivers had discussed when to restart their child's vaccinations with a
262 transplant provider. While 50% were concerned about the safety of vaccines for their child after their
263 BMT treatment, 75% had received an oncology provider recommendation to restart vaccines and 75%
264 intended to do so. We re-ran the regression analyses removing caregivers of BMT survivors and the effect

265 estimates were similar (Oncology: RR: 1.75 95%CI 1.34-2.28, $p < 0.001$ PCP: RR 1.51 95%CI 1.17-1.94,
266 $p = 0.001$). Time since diagnosis was not significant.

267 **Discussion**

268 Timely vaccination is essential for protecting childhood cancer survivors from vaccine-preventable
269 diseases. Over one-third of caregivers in our sample did not intend to restart their child's vaccinations
270 after cancer treatment. Caregivers who had discussed vaccines with a provider – either in oncology or
271 primary care – were approximately 50% more likely to report vaccine intention after childhood cancer
272 treatment. Clinical interventions to convey strong provider recommendations are needed to improve
273 survivors' receipt of immunizations after cancer treatment.

274 Regardless of their vaccine intention, 34.5% of all caregivers felt uncertain about which vaccines their
275 child needed. Caregivers need guidance regarding vaccines after cancer regardless of their child's current
276 vaccination status. While some survivors may require catch-up or booster vaccines, others may simply
277 benefit from a provider recommendation to continue receiving age appropriate vaccination after
278 treatment. This is particularly relevant for caregivers of younger survivors, given that most childhood
279 vaccines are administered under age five [1].

280 Some caregivers exhibited the same resistance to vaccines that is commonly found in the general public,
281 such as worries about vaccine safety [19, 20]. A few caregivers expressed unique concerns that
282 vaccinations may have caused their child's cancer. These concerns demonstrate that caregivers may
283 benefit from direct education on the safety and efficacy of vaccines after cancer treatment. There are
284 resources for information from reputable sources, like the Centers for Disease Control and the American
285 Academy of Pediatrics [21-23], and guidelines for immunocompromised patients [24], that clinicians can
286 use to guide these conversations.

287 We also found that certain caregivers worried that their child's immune system was not yet strong enough
288 to develop immunity to vaccine-preventable diseases. Among those reporting no intent to vaccinate, the

289 majority (68%) were less than one year from diagnosis compared to only 46.3% of those reporting
290 vaccine intention. In our multivariable models, greater time from diagnosis was associated with vaccine
291 intention, potentially because concerns about vaccinating in the initial months after treatment may subside
292 over time. We were unable to investigate other factors such as length of cancer treatment, child's
293 vaccination status prior to diagnosis, and type of treatment, which may complicate providers' vaccine
294 recommendations. It is also possible that caregivers experience with cancer could influence
295 personal vaccination beliefs. However, we found no differences in intention in our analyses
296 (Table 3, $p=0.65$), but this should be confirmed with larger samples. In particular, caregivers'
297 worries about the safety of vaccines after cancer should be considered when developing
298 interventions in both oncology and primary care settings to recommend restarting vaccines after
299 cancer.

300 Without a strong commitment from oncology clinics to take responsibility for vaccinations, or appropriate
301 training of PCPs who care for survivors in the long-term, it is unlikely that vaccine-related educational
302 efforts will reach caregivers of pediatric cancer survivors. However, improving communication between
303 oncologists and PCPs using a shared decision-making model for survivorship care may help [25]. Key to
304 this model is a co-managed transition from oncology to primary care [26]. During this transition,
305 responsibility for preventive care, such as vaccines, is shifted from oncology back to primary care [26].
306 Unfortunately, this transition is complex and current models may be limited by lack of vaccine specific
307 guidance and inadequate communication between oncology and primary care. Communication about
308 restarting vaccines could be initiated by pediatric oncology care teams during the delivery of a
309 survivorship care plan (SCP), an evidence-based tool used to guide the transition from oncology back to
310 primary care settings [27, 28]. As oncologists are highly trusted providers [29,30], this may be an
311 important setting for introducing survivor and caregiver education about timely vaccination adherence
312 after cancer treatment before they transitioning transition back to primary care. At the same time,

313 oncologists can use the SCP as a communication tool with a patient's PCP to improve this transition and
314 help to provide guidance on restarting vaccinations.

315 While our findings demonstrate a need for providers to discuss vaccination with pediatric cancer
316 survivors and their caregivers, barriers to these conversations in an oncology setting may include deferral
317 of responsibility to PCPs, lack of knowledge about which vaccines to recommend and when, and not
318 having procedures in place for vaccinating in the oncology clinic. The ambiguity regarding which
319 provider (oncology vs. PCP) takes responsibility for post-treatment vaccination is perpetuated by the fact
320 that, while many childhood cancer survivors continue to see an oncologist after their cancer treatment,
321 many are also seen contemporaneously by their PCP [31]. To ensure that caregivers of childhood cancer
322 survivors receive appropriate vaccine recommendations and have access to childhood vaccinations,
323 flexibility in shared decision-making between oncology and primary care is needed [26].

324 The generalizability of our findings may be limited by a moderate sample size recruited from a single
325 pediatric oncology clinic. Our sample is primarily Non-Hispanic White and thus, the experiences of
326 caregivers of other races and ethnicities may be underrepresented. Our survey was not anonymous,
327 meaning that positive response bias about vaccine intentions may have influenced our results. Our
328 analytical decision to classify individuals who indicated that their child did not need catch-up/booster
329 vaccines as no intent to vaccinate could have led to outcome misclassification bias. However, in
330 sensitivity analyses, when we removed these caregivers from the regression models, both oncology and
331 PCP recommendations remained very influential. Despite our efforts to reduce misinterpretation, the
332 question used to measure vaccine intention may have surpassed health literacy levels for some
333 participants. We also did not measure how the timing and strength of provider recommendations
334 influences caregiver intentions, both of which have been shown to influence caregiver vaccine intentions
335 in the general population. Caregiver vaccine intentions after childhood cancer treatment likely differs by
336 vaccine type. For example, while we did not account for differences in caregiver's intentions by vaccine
337 type, an earlier report of HPV vaccine intentions showed that one-third of caregivers of childhood cancer

338 who were age-eligible for the HPV vaccine were unlikely-very unlikely to get the HPV vaccine for their
339 child [32]. Finally, there was a significantly lower proportion of rural patients with caregivers in the study
340 (18.7%) compared to non-participants (18.7%, $p=0.02$). Thus, vaccine barriers for rural caregivers (e.g.,
341 travel time, distance) may be underrepresented.

342

343 In summary, provider recommendations, from either an oncologist/cancer care team member or a PCP,
344 highly influence a caregiver's vaccine intentions after childhood cancer treatment. High quality follow-up
345 care for childhood cancer survivors includes childhood vaccinations, but there are no clear guidelines
346 about how to best deliver a provider recommendation for restarting vaccinations after cancer, under what
347 conditions caregivers are most receptive to vaccine recommendations (oncology vs. primary care), and
348 the strengths and limitations of oncology clinics for providing education on vaccines after cancer
349 treatment. These findings can guide future clinical interventions that test the influence of a coordinated
350 oncology and PCP approach vaccine recommendations after cancer using a SCP to educate caregivers and
351 survivors about needed vaccines.

352

353 **Compliance with Ethical Standards**

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362 *Conflict of Interest*

363 All authors declare that we have no conflicts of interest to disclose.

364 *Ethical Approval*

365 All procedures performed in studies involving human participants were in accordance with the ethical
366 standards of the institutional and/or national research committee and with the 1964 Helsinki declaration
367 and its later amendments or comparable ethical standards.

368 *Informed Consent*

369 Informed consent was obtained from all individual participants included in the study.

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TABLE 1 Primary caregiver demographic characteristics by vaccine intention for their child with cancer (N=145)

Caregiver	Total N=145		Vaccine intention (65.5%, n=95)		No intent to vaccinate (34.4%, N=50)		p-value ²
	N	%	N	%	N	%	
Age at survey (years)¹							
18-29	14	9.7	9	9.5	5	10.2	0.03
30-39	79	54.9	60	63.2	19	38.8	
40-49	39	27.1	19	20.0	20	40.8	
50-59	12	8.3	7	7.4	5	10.2	
Relationship to child with cancer¹							
Mother	116	80.6	73	76.8	43	87.8	0.26 ³
Father	25	17.4	19	20.0	6	12.2	
Grandparent and/or Legal guardian	3	2.1	3	3.2	0	0.0	
Gender¹							
Female	116	81.1	74	77.9	42	87.5	0.17
Male	27	18.9	21	22.1	6	12.5	
Education¹							
High school	23	16.2	15	16.1	8	16.3	0.58
Some college/tech	56	39.4	34	36.6	22	44.9	
College graduate	63	44.4	44	47.3	19	38.8	
Race¹							
White	129	90.9	85	90.4	44	91.7	0.54 ³
Other	13	9.1	9	9.6	4	8.3	
Ethnicity¹							
Non-Hispanic	124	89.2	81	89.0	43	89.6	0.92
Hispanic	15	10.8	10	11.0	5	10.4	
Annual household income¹							
<\$20,000	10	7.2	5	5.4	5	10.9	0.83
\$20,000-\$39,999	20	14.5	13	14.1	7	15.2	
\$40,000-\$59,999	26	18.8	17	18.5	9	19.6	
\$60,000-\$79,999	22	15.9	15	16.3	7	15.2	
\$80,000-\$99,999	21	15.2	16	17.4	5	10.9	
>\$100,000	39	28.3	26	28.3	13	28.3	
Insurance status¹							
Insured	133	93.7	90	95.7	43	89.6	0.14 ³
Uninsured	9	6.3	4	4.3	5	10.4	
Marital status¹							
Married/Living as married	127	88.2	87	91.6	40	81.6	0.08
Divorced/Separated/Never married	17	11.8	8	8.4	9	18.4	
Rurality of Residence¹							
Urban	117	81.2	81	85.3	36	73.5	0.08
Rural	27	18.8	14	14.7	13	26.5	

¹Missing for, variable (n): age (1), relation (1), gender (2), education (3), race (3), ethnicity (6), income (7), insurance (3), marital status (1), rurality (1)

²Chi Square test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate . Bold indicates significance at p<0.05.

³Fisher Exact test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate . Bold indicates significance at p<0.05.

TABLE 2 Pediatric cancer survivor demographic characteristics by primary caregivers' vaccine intention for their child with cancer (N=145)

	Total N=145		Vaccine intention (65.5%, n=95)		No intent to vaccinate (34.4%, N=50)		p-value ²
	N	%	N	%	N	%	
Age at survey (years)							
0-4	25	17.2	20	21.0	5	10.0	0.01
5-9	52	35.9	37	39.0	15	30.0	
10-14	37	25.5	25	26.3	12	24.0	
15-20	31	21.4	13	13.7	18	36.0	
Gender							
Female	71	49.0	52	54.7	19	38.0	0.05
Male	74	51.0	43	45.3	31	62.0	
Race¹							
White	129	89.6	85	90.4	44	88.0	0.65
Other	15	10.4	9	9.6	6	12.0	
Ethnicity¹							
Non-Hispanic	120	85.7	79	85.9	41	85.4	0.94
Hispanic	20	14.3	13	14.1	7	14.6	
Insurance status¹							
Insured	141	97.9	92	97.9	49	98.0	0.72 ³
Uninsured	3	2.1	2	2.1	1	2.0	
Age at diagnosis (years)							
0-4	53	36.6	45	47.4	8	16.0	<0.01
5-9	39	26.9	23	24.2	16	32.0	
10-14	33	22.8	21	22.1	12	24.0	
15-17	20	13.8	6	6.3	14	28.0	
Time since diagnosis							
3 months to <1 year	78	53.8	44	46.3	34	68.0	0.03³
1 to <2 years	56	38.6	41	43.2	15	30.0	
2 to <3 years	11	7.6	10	10.5	1	2.0	
Diagnosis							
Leukemia	54	37.2	42	44.2	12	24.0	0.11
Brain/Central Nervous System	21	14.5	13	13.7	8	16.0	
Lymphoma	26	17.9	14	14.7	12	24.0	
Other	44	30.3	26	27.4	18	36.0	

¹Missing for, variable (n): race (1), ethnicity (5), health insurance (1)

²Chi Square test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate. Bold indicates significance at p<0.05.

³Fishers Exact test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate. Bold indicates significance at p<0.05.

TABLE 3 Factors associated with primary caregivers' vaccine intention for their child with cancer (N=145)

	Total N=145		Vaccine intention (65.5%, n=95)		No intent to vaccinate (34.4%, N=50)		p-value ²
	N	%	N	%	N	%	
Provider recommended catch-up/booster							
Oncologist/cancer care team							
Yes	66	46.8	57	62.0	9	18.4	<0.01
No	75	53.2	35	38.0	40	81.6	
Primary care provider							
Yes	51	37.8	46	52.3	5	10.6	<0.01
No	84	62.2	42	47.7	42	89.4	
Oncologist/cancer care team discuss when to restart vaccine schedule¹							
Yes	66	48.5	58	65.2	8	17.0	<0.01
No	45	33.1	23	25.8	22	46.8	
My child did not need catch-up	25	18.4	8	9.0	17	36.2	
Child has a primary care provider							
Yes	135	93.1	89	93.7	46	92.0	0.38
No	8	5.5	4	4.2	4	8.0	
Don't know	2	1.4	2	2.1	0	0.0	
Primary care provider visit since completing treatment¹							
Yes	115	85.2	78	87.6	37	80.4	0.26
No	20	14.8	11	12.4	9	19.6	
Barriers to completing (select all that apply)							
Distance to clinic	8	5.5	5	5.3	3	6.0	0.56 ³
Time needed to get to clinic	6	4.1	6	6.3	0	0.0	0.08 ³
Scheduling clinic appointments	12	8.3	8	8.4	4	8.0	0.60 ³
Wait time at clinic	3	2.1	2	2.1	1	2.0	0.73 ³
Transportation costs to get to clinic	0	0.0	0	0.0	0	0.0	NA
Cost of clinic visit	3	2.1	2	2.1	1	2.0	0.73 ³
Cost of the vaccine	5	3.4	3	3.2	2	4.0	0.56 ³
Don't know which vaccines to get	50	34.5	30	31.6	20	40.0	0.31
Other	29	20.0	17	17.9	12	24.0	0.38
Vaccine preferences (yes response only)							
Getting recommended vaccines is important	136	96.4	93	97.9	43	93.5	0.20 ³

Vaccinating my child helps protect others	135	94.4	94	99.0	41	85.4	<0.01 ³
Vaccines needed when diseases are rare	136	94.4	95	100.0	41	83.7	<0.01 ³
Vaccines are safe	125	88.6	88	92.6	37	80.4	0.03
Vaccines are effective	137	96.5	94	98.9	43	91.5	0.04
Children develop better immunity by getting sick	24	17.4	12	13.0	12	26.1	0.06
Comfortable discussing vaccine concerns with providers	133	93.0	90	94.7	43	89.6	0.25
Providers give enough info on vaccines/side effects	107	76.4	71	77.2	36	75.0	0.77
Some age-recommended vaccines are unnecessary	17	11.9	8	8.4	9	18.7	0.07
Doctor reluctant to administer requested vaccines	2	1.4	2	2.1	0	0.0	0.43 ³
The cancer diagnosis changed my view of vaccines	24	16.8	15	15.8	9	18.7	0.65

¹Missing for, variable (n): Oncologist/cancer care team recommended catch-up/booster (4), PCP recommended catch-up/booster (10), Oncologist/cancer care team discuss when to restart (9), PCP since completing treatment (10), getting vaccines is important (4), vaccinating my child helps protect others (2), vaccines needed when diseases are rare (1), vaccines are safe (4), vaccines are effective (3), children develop better immunity by getting sick (7), comfortable discussing vaccine concerns with providers (2), providers give enough info on vaccines/side effects (5), some age-recommended vaccines are unnecessary (2), doctor reluctant to administer requested vaccines (2), the cancer diagnosis changed my view of vaccines (2)

²Chi Square test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate. Bold indicates significance at $p < 0.05$.

³Fisher Exact test comparing proportions between caregivers reporting vaccine intention and those reporting no intent to vaccinate. Bold indicates significance at $p < 0.05$.

TABLE 4 Relative risks of provider recommendation for catch-up or booster vaccination with primary caregivers' vaccine intention for their child with cancer

	Model 1			Model 2		
	RR	95%CI	p-value ¹	RR	95%CI	p-value ¹
Oncologist/cancer care team recommendation²						
Yes	1.65	1.27-2.12	<0.01	--	--	--
No	Ref.					
Primary care provider recommendation²						
Yes	--	--	--	1.51	1.19-1.94	<0.01
No				Ref.		
Child's current age (years)	0.97	0.95-0.99	0.01	0.97	0.94-1.00	0.04
Time since diagnosis (years)	1.22	1.04-1.44	0.02	1.24	1.04-1.46	0.01

¹Bold indicates significance at p<0.05.

²Outcomes were missing for: oncologist/cancer care team (n=4), primary care provider (n=10). All listed variables included in each model.