Immunotherapy with oligomannose-coated liposomes ameliorates allergic symptoms in a murine food allergy model

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Original Articles

Title: Immunotherapy with oligomannose-coated liposomes ameliorates allergic symptoms in a murine food allergy model.

Short title: Immunotherapy with oligomannose-coated liposomes

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20 **Abstract**

21 **Background:** Allergen-specific immunotherapy has been anticipated to be a
22 disease-modifying therapy for food allergies. We previously reported that CD8⁺
23 regulatory T cells may prevent antigen-sensitized mice from developing allergic
24 diarrhea. Because oligomannose-coated liposomes (OML) have been shown to induce
25 MHC class I-restricted CD8⁺ T cell responses, we analyzed the adjuvant activities of
26 OML for inducing regulatory CD8⁺ T cells and mucosal tolerogenic responses in
27 allergen-sensitized mice.

28 **Methods:** BALB/c mice that were previously sensitized to ovalbumin (OVA) were
29 intranasally immunized with OVA-encased in OML (OVA-OML) or OVA-encased in
30 non-coated liposomes (OVA-NL). We assessed allergic diarrhea induced by oral OVA
31 administration, OVA-specific immunoglobulin production, and cytokine production in
32 the intestines and mesenteric lymph nodes (MLNs).

33 **Results:** Intranasal immunization with OVA-OML, but not OVA-NL, suppressed the
34 development of allergic diarrhea. This was associated with *in vitro* Ag-induced IL-10
35 production and the *in vivo* expansion of CD8⁺CD28⁻ and CD4⁺CD25⁺Foxp3⁺ T cell
36 populations among mesenteric lymph node mononuclear cells, and was significantly
37 ablated by anti-SIGNR1 or anti-CR3 mAbs. Up-regulation of serum OVA-specific IgE

was suppressed, whereas OVA-specific IgG1, IgG2a, and soluble IgA production were enhanced by intranasal administration of OVA-OML. Adoptive transfer of CD8⁺CD28⁻ T cells but not CD8⁺CD28⁺ T cells from the MLNs of OVA-OML-treated mice ameliorated the development of diarrhea.

Conclusion: These results suggest that intranasal immunization with Ag-encased OML may be an effective immunotherapy for food allergies, as it induces a subset of regulatory CD8⁺ T cells as well as CD4⁺CD25⁺Foxp3⁺ T cell and modulates humoral immune responses in allergen-sensitized mice.

Key Words: food allergy; liposome; mouse model; oligomannose; regulatory T cells

Word count: 2484

52 Introduction

53 Food allergy is often associated with aberrant Th2-type immune responses and the
54 breakdown of oral tolerance to food antigens (Ags). Recently, a number of
55 immunotherapeutic approaches have been reported that focused on the induction of oral
56 tolerance (1, 2). Classical allergen-specific immunotherapy for food allergy by
57 delivering Ag via the subcutaneous route can result in severe adverse reactions. Thus,
58 appropriate Ag delivery routes and systems are needed to improve Ag targeting to the
59 mucosal immune system.

60 The reduction of food allergy symptoms by immunotherapy or by outgrowing them
61 has been hypothesized to be mediated by the induction of regulatory T cells, as well as
62 by a shift from a Th2 to a Th1 response, and/or by the balance between allergen-specific
63 IgE and IgG antibodies, which may regulate mast cell and basophil activities (3, 4). We
64 recently demonstrated that inducible CD8⁺ T cells may prevent Ag-sensitized mice from
65 developing allergic diarrhea (5). Thus, manipulating CD8⁺ regulatory T cells is
66 anticipated to be a novel therapeutic strategy for food allergy.

67 Presentation of exogenous Ags on MHC class I molecules, termed cross-presentation,
68 is essential for the induction of CD8⁺ T-cell responses (6-8). Several studies have
69 demonstrated that Ag mannosylation or mannosylated Ag delivery systems, such as

mannosylated-liposomes, could enhance not only MHC class II-, but also MHC class I-restricted Ag presentation and T cell stimulation by targeting mannose receptors on APCs (9, 10). Recently, oral delivery of highly mannonnosylated Ag has been shown to selectively target dendritic cells in the lamina propria via specific ICAM-3 grabbing non-integrin-related 1 (SIGNR1) and, thereby, induce the generation of CD4⁺ type 1 regulatory T (Tr1)-like cells that expressed IL-10 and interferon- γ (11). However, incorporating new glycosylation sites by genetic engineering or by direct attachment of mannose residues to non-glycosylated Ags may compromise their inherent immunogenicity.

Kojima *et al.* (12) reported that liposomes coated with synthetic neo-glycolipids comprised of mannotriose and dipalmitoylphosphatidylcholine (oligomannose-coated liposomes; OML) induced a Th1-like immune response with cytotoxic T cells specific for Ags encased in the liposomes following subcutaneous or intraperitoneal administration (12, 13). Intranasal delivery of OML was shown to induce both mucosal and systemic immune responses (14). SIGNR1 acts as a receptor for the recognition of OML (15). These results led us to hypothesize that OML could be used as a mucosal adjuvant to induce regulatory CD8⁺ T cells, Tr1-type immunity, and mucosal immune responses.

88 The aim of this study was to determine whether intranasal administration of OML
89 could induce mucosal tolerogenic responses in mice that had been previously sensitized
90 to OVA, a model food Ag. Our results indicate that intranasal administration of OML
91 induces regulatory CD8⁺ T cells and Ag-specific secretory IgA in localized tissues of
92 OVA-sensitized mice and, thereby, ameliorates the development of allergic diarrhea.

93 **Materials and methods**

94 **Food allergy animal models**

95 BALB/c mice were bred under standard pathogen-free conditions. All animal
96 experiments were performed in accordance with institutional guidelines as approved by
97 the Animal Care Review Board of the University of Fukui. Six-week-old female mice
98 were sensitized to OVA or ovomucoid (OM) (Sigma-Aldrich Co., St. Louis, MO) by
99 intraperitoneal injection of 100 µg of OVA or OM in alum (Imject Alum, Thermo
100 Scientific, Rockford, IL) on days -35 and -21. Beginning on day 0, the sensitized mice
101 received challenges by oral gavage of 20 mg OVA or OM dissolved in 0.2 ml PBS every
102 other day for up to 6 doses. Before each intragastric challenge, mice were deprived of
103 food for 2 hours. Diarrhea was assessed visually and body temperature was monitored
104 for up to 1 hour following intragastric challenge.

105

106 **OVA-OML and treatments**

107 OVA-encased in oligomannose-coated liposomes (OVA-OML) and control
108 OVA-encased in non-coated naked liposomes (OVA-NL) were purchased from Bio Med
109 Core Inc. (Yokohama, Japan). The OML were comprised of
110 dipalmitoylphosphatidylcholine : cholesterol:

mannotriose-dipalmitoylphosphatidylethanolamine (10:10:1) with a particle size of 1 μm (13). OVA-OML, OVA-NL, or OVA PBS solution (20 μl /dose each), containing 0.2 μg OVA/dose, was administrated into the left side of the nose of sensitized mice by intranasal instillation over 5 minutes for up to 5 doses from days -14 to -10. Anti-SIGNR1 mAb (ER-TR9) (AbD Serotec, Oxford, UK), or anti-complement receptor 3 (CR3) mAb (M1/70) (AbD Serotec), or control rat Ig (2 μg /dose) was intranasally administrated 5 minutes before each intranasal instillation of OVA-OML.

Adoptive transfer of primed CD8⁺ T cells

Total CD8⁺ T cells, and CD28⁺ and CD28⁻ CD8⁺ T cell subsets were purified from mesenteric lymph nodes (MLNs) of OVA-sensitized and challenged mice using MACS CD8⁺ T cell Isolation Kits (Milteni Biotec GmbH, Bergish Gladbach, Germany) and a FACSCanto II (BD Biosciences). A total of 0.8×10^6 CD8⁺ T cells, CD28⁺CD8⁺ T cells, or CD28⁻CD8⁺ T cells per mouse were adoptively transferred into OVA-sensitized mice by intravenous injection on day -1.

Monoclonal antibodies and flowcytometry

Anti-mouse CD3, CD4, CD8, CD25, CD28, CD103, CD122, and CTLA-4 mAbs

were purchased from BD Biosciences. Cells were stained using standard procedures and analyzed with a FACSCalibur (BD Biosciences).

Cell culture

Twenty-four hours after the last OVA challenge, mononuclear cells from MLNs were isolated. Cells (1×10^5 /well) were cultured either with medium alone (RPMI 1640 supplemented with 50 mM HEPES, 100 U/ml penicillin, 100 μ g/ml streptomycin, 2×10^{-5} M 2-mercaptoethanol, and 10% heat inactivated fetal calf serum (Sigma-Aldrich Co.) or with OVA (1 mg/ml) for 72 h. Supernatants were collected for cytokine measurements.

Cytokine and OVA-specific antibody measurements

IL-4, IL-10, and IFN- γ in the culture supernatants were measured by a two-site sandwich ELISA, as described previously (5). Serum levels of OVA-specific IgG1, IgG2a, and IgE and the concentration of OVA-specific secretory IgA in intestinal lavage fluids, obtained by washing 10 cm of intestine with 1 ml of PBS, were determined by ELISAs, as described previously (5).

Real-time polymerase chain reaction

Total RNA was isolated from samples of the jejunum and mRNA levels were quantified as described previously (5). Results were expressed as relative units, which were calculated by the comparative Ct method.

Statistical analysis

Results are given as means $\pm$ standard errors of the mean. Comparisons of 2 groups used unpaired Student's *t*-tests, unless an *F*-test showed that the variances were significantly different. When variances were significantly different, Welch's test was used. Comparisons of the occurrences of diarrhea were made by Kaplan-Meier survival analysis. A *p*-value < 0.05 was considered statistically significant.

Results

Nasal immunization with OVA-OML alleviates allergic diarrhea

As previously described (5, 16, 17), the OVA- and OM-sensitized mice developed allergic diarrhea accompanied by hypothermia after repetitive intragastric OVA and OM challenges, respectively (Fig. 1B and 1C). Intranasal instillation of OVA-OML inhibited the development of allergic diarrhea and hypothermia in OVA-sensitized and challenged mice, but not in OM-sensitized and challenged mice, indicating that the effects of immunotherapy with OML is Ag-specific.

In the jejunum of OVA-sensitized mice, intragastric OVA challenges increased the infiltration of eosinophils and the mRNA expression of IL-4, IFN- γ , IL-10, and TGF- β with a Th2 dominant pattern and increased mucosal mast cell protease-1 (mmcp1) mRNA expression (Fig. 1D - F). Immunotherapy with intranasal instillation of OVA-OML significantly suppressed the accumulation of eosinophils and the mRNA up-regulations of mmcp1 and IL-4, while it marginally reduced the mRNA expression of IFN- γ , IL-10, and TGF β 1.

Oligomannose residues are essential for the adjuvant effects of OML.

We next asked whether the oligomannose residues on liposomes were critical for the

177 suppressive effects of intranasal instillation of OVA-OML. OVA-sensitized mice were
178 intranasally immunized with OVA entrapped in carbohydrate-uncoated, bare liposomes
179 (OVA-NL) or OVA alone. Intranasal instillation of OVA-NL or OVA alone did not
180 inhibit the development of allergic symptoms, the accumulation of eosinophils, and the
181 increases in IL-4 and mmcp1 mRNA expression in the jejunum (Fig. 2).

182
183 **Intranasal immunization with OVA-OML modulates Ag-specific immunoglobulin**
184 **production.**

185 Before OVA challenges there were no significant differences in the serum levels of
186 OVA-specific IgE, IgG1 and IgG2a Abs between OVA-OML-treated mice and untreated
187 mice (Fig. 3). After repetitive challenges, the serum OVA-specific IgE levels of
188 OVA-OML-treated mice were lower than those of untreated mice, whereas the serum
189 levels of OVA-specific IgG1 and IgG2a and the concentration of secretory
190 OVA-specific IgA in the intestinal lavage fluids of OVA-OML-treated mice were higher
191 than those of untreated mice.

192
193 **OVA-OML treatment modifies the phenotype and function of MLN cells**

194 Because MLNs play critical roles in the development of food allergy and oral

tolerance (17, 18), we analyzed *in vitro* OVA-induced cytokine production by MLN mononuclear cells purified from the mice after repetitive OVA challenges. Intranasal immunization with OVA-OML significantly increased the *in vitro* OVA-induced IL-10 production by MLN mononuclear cells, but did not significantly affect OVA-induced IL-4 and IFN- γ production (Fig. 4A).

To assess the expansion of regulatory T cell populations in MLNs after intranasal immunization with OVA-OML, we analyzed MLN T cell subsets. As shown in Fig 4B, the frequencies of CD4⁺Foxp3⁺ T cells, and CD8⁺CD28⁻ T cells, but not that of CD8⁺CD122⁺T cells, or CD8⁺CD103⁺T cells among MLN T cells significantly increased in the intranasally-immunized mice compared with non-immunized mice.

Adoptive transfer of MLN CD8⁺ T cells alleviates allergic diarrhea.

To determine whether the MLN CD8⁺ T cells functioned as regulatory T cells *in vivo* to inhibit the development of allergic diarrhea, mononuclear cells or CD8⁺ T cells that were purified from OVA-OML-treated or untreated mice after repetitive OVA challenges were adoptively transferred to other OVA-sensitized mice. As shown in Fig 5, adoptive transfer of CD8⁺ T cells from OVA-OML-treated mice, but not from untreated mice, significantly inhibited the development of diarrhea and hypothermia. These cells

also abrogated the up-regulation of mmcp1 and IL-4 mRNA expression in the intestine, although to a lesser extent. Adoptive transfer of CD8⁺ T cells from OVA-OML treated mice slightly, but significantly, suppressed the up-regulation of serum levels of OVA-specific IgE and enhanced serum OVA-specific IgG2a levels, but did not affect OVA-specific secretory IgA levels in intestinal lavage fluids (Figure 5).

To characterize the phenotype of CD8⁺ T cells with these suppressive effects, CD28⁻CD8⁺ T cells were purified from MLNs of OVA-OML-treated mice using fluorescence-activated cell sorting. CD28⁻CD8⁺ T cells were responsible for the suppressive effects on the allergic symptoms *in vivo*, whereas CD28⁺CD8⁺ T cells had little, if any, effect (Figure 6A-C).

SINGNR1 and CR3 are necessary for the therapeutic effects of OVA-OML.

Since CR3 is known to cooperatively act with SIGNR1 as a receptor for recognition and uptake of OMLs (15), we administered anti-SIGNR1 mAb or anti-CR3 mAb to OVA-sensitized mice before intranasal instillation of OVA-OML. The suppressive effects of intranasal instillation of OVA-OML were significantly ablated by anti-SIGNR1 mAb or anti-CR3 mAb (Figure 6D-F).

Discussion

In the present study, we examined a novel therapeutic approach for food allergy using intranasal immunization of Ag entrapped in OML. The mechanisms of intranasal immunotherapy with OML appeared to be due (1) to the induction of regulatory CD8⁺ T cells, primarily among the CD28⁻CD8⁺ T cell population, as well as CD4⁺CD25⁺Foxp3⁺ T cells and (2) to the modulation of humoral immune responses, including enhanced Ag-specific IgGs and secretory IgA production and suppressed up-regulation of Ag-specific IgE. SIGNR1 and CR3 are involved in the therapeutic effects of OVA-OML.

Various phenotypes of regulatory CD8⁺ T cells have been identified in different experimental systems (19, 20). In an experimental inflammatory bowel disease model, naturally occurring CD8⁺CD28⁻CD122⁻ regulatory T cells inhibited IFN- γ production by colitogenic CD4⁺ T cells and prevented colitis. (21). Intraperitoneal application of zwitterionic capsular polysaccharides of commensal bacteria increased CD8⁺CD28⁻ T cells, which exhibited immunosuppressive properties on CD4⁺ T cells (22). The expanded CD8⁺CD28⁻ T cell population found in the MLNs of OVA-OML immunized mice displayed a more robust regulatory function than did the CD8⁺CD28⁺ T cell population *in vivo*, suggesting that the therapeutic effects of OML instillation could be

249 attributed, in part, to the induction of CD8⁺CD28⁻ regulatory T cells.

250 Treatment of peanut Ag-sensitized mice with a Chinese herbal medicine preparation
251 (FAHF-2) prevented oral Ag-challenge-induced anaphylaxis (23). The inhibitory effect
252 of FAHF-2 was mediated by increased IFN- γ production by CD8⁺ T cells. By
253 comparison, we recently demonstrated that the IL-10-producing capability of CD8⁺ T
254 cells and IL-10 expression by MLNs were associated with alleviating allergic diarrhea
255 (5). IL-10 and TGF- β play essential roles in the suppressive activities of CD8⁺CD28⁻
256 regulatory T cells (21, 22). Takayama et al. (24) reported that IL-10-producing
257 CD4⁺CD25⁺Foxp3⁺ T cells in Peyer's patches inhibited the development of allergic
258 diarrhea. Intranasal immunization with OVA-OML increased the percentages of
259 CD4⁺CD25⁺Foxp3⁺ T cells and CD28⁻CD8⁺ T cells, and enhanced Ag-induced IL-10
260 production by MLN cells *in vitro*. IL-10 rather than IFN- γ production by MLNs may be
261 involved in the therapeutic effects of OVA-OML immunization.

262 It is well known that the production of IgG1 and IgE is regulated by a Th2 response,
263 whereas IgG2a production is regulated by a Th1 response (25). Immunotherapy with
264 OVA-OML enhanced the up-regulation of both OVA-specific IgG2a and IgG1,
265 indicating no appreciable shift from Th2- to Th1-dominant humoral responses.
266 IL-21R^{-/-} mice exhibit impaired Ag-specific IgG1 production and augmented

Ag-specific IgE production (26). Although IL-21 was not detected in the supernatants of OVA-stimulated MLN mononuclear cells (data not shown), IL-21 might explain the discordant IgE and IgG1 responses in OVA-OML-treated mice. Schmitz *et al.* (27) reported that immunotherapy with recombinant cat allergen displayed on virus-like particles induced allergen-specific IgG1 production and abolished an IgE memory response in allergen-sensitized mice and that the allergen-specific IgG antibodies alleviated allergic symptoms in FcγRIIb-dependent and independent manners. The enhanced OVA-specific IgG1 and IgG2a production might also account for the therapeutic effects of OVA-OML immunotherapy.

Actively tolerized mice were found to have higher fecal Ag-specific IgA titers than anaphylactic mice (28). Adoptive transfer of CD8⁺ T cells from OVA-OML immunized mice failed to induce OVA-specific secretory IgA production and tended to exhibit weaker inhibitory effects on the development of food allergy than OVA-OML immunization itself (Fig. 2 and Fig. 5). Although this might have been due to the small number of transferred CD8⁺ T cells, secretory IgA may also play a protective role against the development of food allergy by preventing the uptake of food Ag with intact epitopes from mucosal surfaces.

In summary, our results demonstrate that Ag entrapped in OML has potential uses for

treating established allergies and at least two different mechanisms may be involved: induction of regulatory T cells and modulation of humoral immunity. It is difficult to determine the relative contributions of CD8⁺CD28⁻ and CD4⁺CD25⁺Foxp3⁺ T cells and humoral immunity to OML-induced suppression of food allergic symptoms. Multiple mechanisms may act synergistically suppress of allergic symptoms. Because OML are comprised of innocuous materials, are ubiquitously distributed throughout the body (29), they could be useful as an immunotherapy adjuvant and Ag delivery system for food allergy.

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Conflict of interest: The authors declare that they have no conflict of interest.

Author contribution: A.K. and H.S. contributed equally to this work. Each named author in this report contributed to its content either through being integral to the experimental planning and/or its implementation at the bench.

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Figure legends

Figure 1. Intranasal immunization with OVA-OML ameliorates the development of allergic diarrhea. (A) Experimental protocol. (B) Diarrhea occurrence following repetitive challenges and (C) body temperature changes after the last challenge in non-immunized, OVA-sensitized mice (open circles), non-immunized, OM-sensitized mice (open squares), OVA-OML-immunized, OVA-sensitized mice (closed circles), or OVA-OML-immunized, OM-sensitized (closed squares); $n = 12/\text{group}$. (D) Jejunum of negative control non-challenged, positive control non-immunized or OVA-OML immunized OVA-sensitized mice. (E) Numbers of eosinophils and (F) cytokine and mmcp1 mRNA expression in the jejunum of positive control non-immunized mice (filled bars) and OVA-OML immunized mice (hatched bars) after the last challenge. Results for non-sensitized mice (open bars) and sensitized mice (dotted bars) without challenges are negative controls. Results are means $\pm$ SE ($n = 6$) and are representative of 3 independent experiments. Kaplan-Meier survival analysis, unpaired Student's t -tests, and Welch's tests were used for statistical analysis. $*p < 0.05$, $**p < 0.01$

Figure 2. Intranasal immunization with OVA-NL or OVA alone fails to suppress the development of allergic diarrhea and hypothermia. (A) Experimental protocol. (B)

Diarrhea occurrence following repetitive challenges and (C) body temperature changes after the last challenge in non-immunized mice (open circles) or in mice immunized with OVA alone (closed squares), OVA-NL (open squares), or OVA-OML (closed circles); $n = 12/\text{group}$. (D) IL-4, (E) mmcp1 mRNA expression, and (F) numbers of infiltrated eosinophils in the jejunum of non-immunized mice or mice immunized with OVA alone, OVA-NL, or OVA-OML after challenges. Results for non-sensitized or sensitized mice without challenges are negative controls. Results are means $\pm$ SE ($n = 6$) and are representative of 3 independent experiments. Kaplan-Meier survival analysis, unpaired Student's t -tests and Welch's tests were used for statistical analysis. $*p < 0.05$, $**p < 0.01$

Figure 3. Intranasal immunization with OVA-OML modulates Ag-specific immunoglobulin production. Serum OVA-specific (A) IgE, (B) IgG1 and (C) IgG2a concentrations of non-immunized (open circles) or OVA-OML-immunized mice (closed circles) were determined at pre-immunization, and at pre- and post-challenges. (D) OVA-specific secretory IgA in the intestinal lavage fluid was determined after challenges. Results are means $\pm$ SE ($n = 6$) and are representative of 3 independent experiments. Unpaired Student's t -tests and Welch's tests were used for statistical

analysis. $*p < 0.05$

Figure 4. Intranasal immunization with OVA-OML enhances OVA-induced IL-10 production by MLN mononuclear cells *in vitro* and alters MLN T cell populations. (A) *In vitro* OVA-induced IL-4, IFN- γ , and IL-10 production by MLN mononuclear cells purified from non-immunized (open bars) and OVA-OML-immunized (filled bars) mice after challenges. Results are means $\pm$ SE ($n = 6$) and are representative of 3 independent experiments. Unpaired Student's *t*-tests were used for statistical analysis. $*p < 0.05$ (B) Results for cell surface phenotypes of MLN T cells from non-immunized and OVA-OML-immunized mice after challenges were obtained by gating on CD3⁺ cells. Indicated values are the percentages of each subset among MLN T cells. Results of one representative experiment of 6 are shown.

Figure 5. Adoptive transfer of MLN CD8⁺ T cells from OVA-OML-treated mice ameliorates allergic diarrhea. (A) Experimental protocol. (B) Diarrhea occurrence following repetitive challenges and (C) body temperature change after the last challenge in non-transferred mice (open circles), mice with CD8⁺ T cells transferred from non-immunized controls (open squares), and OVA-OML immunized mice (closed

squares); $n = 12/\text{group}$. (D) IL-4 and (E) mmcp1 mRNA expression in the jejunum, serum OVA-specific (F) IgE, (G) IgG1, and (H) IgG2a concentrations, and (I) OVA-specific secretory IgA in the intestinal lavage fluid from non-transferred mice or from mice with MLN CD8^+ T cells transferred from non-immunized or OVA-OML immunized mice. mRNA expression for non-sensitized and sensitized mice without challenges are negative controls. Results are means $\pm$ SE ($n = 6$) and are representative of 3 independent experiments. Kaplan-Meier survival analysis, unpaired Student's t -tests, and Welch's tests were used for statistical analysis. * $p < 0.05$

Figure 6. Adoptive transfer of MLN $\text{CD28}^-\text{CD8}^+$ T cells but not $\text{CD28}^+\text{CD8}^+$ T cells ameliorates allergic diarrhea. (A) $\text{CD28}^-\text{CD8}^+$ T cells and $\text{CD28}^+\text{CD8}^+$ T cells were purified from MLNs mononuclear cells. (B) Diarrhea occurrence following repetitive challenges and (C) body temperature change after the last challenge in non-transferred mice (open circles), or in mice with $\text{CD28}^-\text{CD8}^+$ T cells (closed squares) or $\text{CD28}^+\text{CD8}^+$ T cells (open squares) ($0.8 \times 10^6/\text{mouse}$) transferred from OVA-OML immunized mice; $n = 8/\text{group}$). (D) Experimental protocol for anti-SIGNR1 and anti-CR3 mAb treatments (E) Diarrhea occurrence following repetitive challenges and (F) body temperature change after the last challenge in non-immunized mice (open circles), or in mice

463 pre-treated with control Ig (closed circles), anti-SIGNR1 mAb (open squares), or
464 anti-CD11b mAb (closed squares); n = 12/group. Kaplan-Meier survival analysis was
465 used for statistical analysis. * $p < 0.05$

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6