Interleukin-17A Deficiency Accelerates Unstable Atherosclerotic Plaque Formation in Apolipoprotein E-Deficient Mice

Danzaki, Keiko; Matsui, Yutaka; Ikesue, Masahiro; Ohta, Daichi; Ito, Koyu; Kanayama, Masashi; Kurotaki, Daisuke; Morimoto, Junko; Iwakura, Yoichiro; Yagita, Hideo; Tsutsui, Hiroyuki; Uede, Toshimitsu

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Supplemental Material

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Keiko Danzaki, Yutaka Matsui, Masahiro Ikesue, Daichi Ohta, Koyu Ito, Masashi Kanayama, Daisuke Kurotaki, Junko Morimoto, Yoichiro Iwakura, Hideo Yagita, Hiroyuki Tsutsui, and Toshimitsu Uede

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Expanded Materials and Methods

Mice

IL-17A-deficient mice used in this study were created as described previously\(^1\).

C57BL/6 ApoE-deficient male mice (ApoE\(^{−/−}\)) (backcrossed 10 times; The Jackson Laboratory, Bar Harbor, ME) were bred with IL-17A-deficient (IL-17A\(^{+/−}\)) female mice on a C57BL/6 background (backcrossed 10 times). Heterozygous F1 progeny were
interbred to yield F2 genotypes. IL-17A wild-type (WT) and IL-17A-deficient mice among ApoE-deficient mice were designated as ApoE\(^{-/-}\) and ApoE\(^{-/-}\)IL-17A\(^{-/-}\), respectively. These mice were intercrossed to yield ApoE\(^{+/-}\) and ApoE\(^{+/-}\)IL-17A\(^{+/-}\), which served as subjects in this experiment on a C57BL/6 background. ApoE deficiency in these mice was defined by a phenotype of elevated serum cholesterol in blood as described previously\(^2\). IL-17A genotyping was performed by polymerase chain reaction analysis of tail DNA as described previously\(^1\). All animal protocols were approved by the committee on animal experimentation of Hokkaido University.

**Diet and experimental design in the high-fat diet model**

Male ApoE\(^{-/-}\) and ApoE\(^{-/-}\)IL-17A\(^{-/-}\) mice whose body weights were between 16.0 and 22.0 g were weaned at 6-8 weeks of age and fed an atherogenic high-fat diet (HFD) (0.15% cholesterol and 21% milk fat, 57BD; TestDiet, Richmond, USA) or normal chow diet ad libitum. Eight or 16 weeks after HFD or normal chow diet feeding, the mice were killed, and atherosclerosis was determined using an en face method\(^2\). The heart and aorta from the aortic root to the iliac branch were removed; aortae were fixed in 10% phosphate-buffered formalin for histopathology. Aortic roots were embedded in OCT compound (Sakura Finetek) and stored at -80°C. The blocks were sectioned at 10
or 6 µm thickness and fixed for 10 min in 10% phosphate-buffered formalin at R.T. or acetone at -20°C.

**Analysis of atherosclerotic lesions**

The degree of atherosclerosis was determined by quantifying oil red O staining in en face lesions in pinned-out aortae. Briefly, the mice were perfused with PBS followed by 10% phosphate-buffered formalin. The aorta was opened longitudinally from the aortic root to the iliac branch and from the iliac bifurcation to a point equidistant from the aortic valve. The brachiocephalic artery was removed, pinned out flat on a black wax surface, and stained with oil red O. The aortas were then photographed, and the total surface and entire lesion areas were measured by planimetry.

**Histopathology**

Serial 6-µm sections were taken from the aortic valve or abdominal aorta area. Sections were fixed for 10 min in acetone at -20°C and used for immunohistochemistry. In another experiment, sections (10 µm thick) were fixed for 10 min in 10% phosphate-buffered formalin and oil red O stain or hematoxylin and eosin (H&E) to determine the plaque area.
Immunohistochemistry

A monoclonal antibody against $\alpha$-smooth muscle actin ($\alpha$-SMA), clone 1A4, was purchased from Sigma-aldrich. A monoclonal antibody against macrophages, MOMA-2, was purchased from Serotec. A rabbit polyclonal antibody against type I collagen was purchased from Abcam (ab21286). The sections were stained with MOMA-2 or 1A4 followed by biotin-conjugated goat anti-rat IgG (for MOMA-2) or rabbit anti-mouse IgG (for $\alpha$-SMA, 1A4) followed by streptavidin-biotin peroxidase complex (Histofine kit; Nichirei). The sections were stained with an antibody against type I collagen, followed by horse radish peroxidase (HRP)-conjugated goat anti-rabbit IgG. The sections were subsequently counterstained with hematoxylin.

Lipid measurements and serum immunoglobulin titration

Serum levels of total cholesterol (Determiner TC555; KYOWA MEDEX), triglycerides (Determiner TG; KYOWA MEDEX), and high density lipoprotein (HDL) cholesterol (Determiner HDL; KYOWA MEDEX) were measured. Serum immunoglobulin (Ig) isotypes (IgG, IgG$_1$, IgG$_2$$_a$, and IgM) and malondialdehyde (MDA)-low density lipoprotein (LDL)-specific antibodies were measured as described previously. To quantify MDA-LDL-specific antibodies, plates were coated with 100 $\mu$g/mL
MDA-LDL, washed, and blocked; sera were subsequently added at an optimized 1:100, 1:1,000 or 1:10,000 dilutions, and specific detection antibodies for IgG1, IgG2a (BETHYL), IgG, and IgM (Jackson ImmunoResearch Laboratories) were added.

MDA-LDL was prepared as described previously5.

### Cytokine analysis

Eight weeks or 16 weeks after HFD feeding, spleen cells were removed and single-cell suspensions were obtained by passing the cells through a 100-μm cell strainer. CD4+ T cells were isolated from these cells using MACS separation columns (25 MS) with CD4 microbeads (L3T4; Miltenyi Biotec). These cells were stimulated in microwell cultures (6 x 10^5/well) with 20 ng/mL phorbol 12-myristate 13-acetate (PMA; Sigma-Aldrich) and 250 ng/mL ionomycin (Sigma-Aldrich) in RPMI 1640 medium supplemented with 10% FBS, 100 U/mL penicillin, and 100 μg/mL streptomycin (Wako). Supernatants were collected at 72 h and analyzed by ELISA for IFN-γ, IL-5, IL-4, IL-6, IL-10 (BD Biosciences), IL-17A (R & D Systems) and IL-17C (Uscn Life Science Inc).

### Intracellular cytokine staining
Murine splenic CD4⁺ T cells were cultured with 20 ng/mL PMA, 250 ng/mL ionomycin, and 1 μL/mL GolgiPlug (BD Biosciences) for 5.5 h. The cells were washed with FACS buffer (0.5% bovine serum albumin and 0.05% NaN₃ in PBS) and blocked with rat anti-mouse Fc receptor antibody, CD16/CD32 (2.4G2; BD Biosciences). The cells were then labeled with FITC-anti-CD3ε (145-2C11; BioLegend) and PE/Cy5-anti-CD4 (RM4-5; BioLegend). Next, the cells were fixed and permeabilized with BD Cytofix/Cytoperm (BD Biosciences). Intracellular cytokines were stained with PE-anti-IL-17A (BD Biosciences) and Alexa Fluor 647-anti IFN-γ (XMG1.2; BioLegend). All analyses were performed on a FACS Calibur flow cytometer (BD Biosciences) with FlowJo software (Tree Star).

**Experimental design for exogenous IL-17A administration**

ApoE⁻/⁻ mice at ages of 6-8 weeks, fed the HFD for 12 weeks were used in this study. Additionally, ApoE⁺/⁻ IL-17A⁻/⁻ mice at ages of 5 weeks, fed the HFD for 10 weeks were used. Both groups of mice were treated with recombinant mouse IL-17A (eBioscience) (2 μg/mouse) diluted in PBS 0.05% mouse albumin (Sigma) (200 μL/mouse) or PBS 0.05% albumin twice a week during HFD feeding.
Statistical analysis

Results are expressed as mean (SEM). Statistical significance between groups was estimated using Student’s t-test; \( p < 0.05 \) was considered statistically significant.
Supplemental Figure Legends

Supplemental Figure I. IL-17A deficiency did not affect atherosclerotic plaque formation in ApoE\textsuperscript{-/-} mice under normal chow diet feeding.

Atherosclerotic plaque formation was quantitatively analyzed by staining of aortae with oil red O. ApoE\textsuperscript{-/-} and ApoE\textsuperscript{-/-}IL-17A\textsuperscript{-/-} mice: day 0 (n = 5; each group), 8 weeks after normal chow diet feeding (normal diet 8w; n = 4 and 3, respectively), 16 weeks after normal chow diet feeding (normal diet 16w; n = 6; each group). *p < 0.05. **p < 0.005.

N.S. denotes difference between two groups is not significantly different.

Supplemental Figure II. Atherosclerotic plaque area of abdominal aorta area was decreased in ApoE\textsuperscript{-/-}IL-17A\textsuperscript{-/-} mice compared to ApoE\textsuperscript{-/-} mice.

A. Representative microphotographs of abdominal aortic sections stained with H&E in ApoE\textsuperscript{-/-} and ApoE\textsuperscript{-/-}IL-17A\textsuperscript{-/-} mice after 8 weeks of HFD feeding. Scale bars indicate 30 \textmu m. B, Quantitative analysis of plaque areas in both ApoE\textsuperscript{-/-} (n= 8) and ApoE\textsuperscript{-/-}IL-17A\textsuperscript{-/-} (n= 8) mice. *p < 0.05.
Supplemental Figure III. Type I collagen-positive area was decreased in ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> mice compared to ApoE<sup>−/−</sup> mice

A, Representative microphotographs of aortic root sections stained with type I collagen in ApoE<sup>−/−</sup> and ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> mice after 8 weeks of HFD feeding. Scale bars in upper panels indicate 300 μm and in under panels indicate 50 μm. B, Quantitative analysis of the percentage of type I collagen-positive areas in both ApoE<sup>−/−</sup> (n= 4) and ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> (n= 11) mice. *p < 0.05.

Supplemental Figure IV. IL-17A deficiency did not significantly affect IL-4, IL-6, IL-10, and IL-17C production in ApoE<sup>−/−</sup> mice.

Quantitative analysis of IL-4 (A), IL-6 (B), IL-10(C), and IL-17C (D) production in the supernatants of splenic CD4-positive T cells from ApoE<sup>−/−</sup> and ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> mice before (n= 4 and 6, respectively) and after 8 (n= 5 and 8, respectively) or 16 (n= 4 and 7, respectively) weeks of HFD feeding. Splenic CD4-positive T cells were cultured in vitro with PMA and ionomycin; culture supernatants were examined by ELISA. Data were obtained from at least three independent experiments. *p < 0.05. N.D. denotes not detectable.
Supplemental Figure V. IL-17A deficiency did not significantly affect production of MDA-LDL-specific IgG2a, IgG, and IgM antibodies in ApoE<sup>−/−</sup> mice after HFD feeding.

Quantitative analysis of titers of MDA-LDL-specific antibodies, IgG2a(A), IgG(B), and IgM(C) in ApoE<sup>−/−</sup> (n= 21) and ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> (n= 35) mice before and after 8 or 16 weeks of HFD feeding. Values are indicated by the relative protein levels against MDA-LDL-specific antibody titers of ApoE<sup>−/−</sup> mice at day 0 and value at day 0 was set as 1. *p < 0.05. **p < 0.0005. N.S., not significantly different. Note that only IgM class of anti-MDA-LDL antibody was reduced in ApoE<sup>−/−</sup>IL-17A<sup>−/−</sup> compared to ApoE<sup>−/−</sup> mice at 16 weeks after HFD feeding.
References


Supplemental Figure I
Supplemental Figure II

A

B

ApoE−/−  
ApoE−/−IL-17A−/−

Supplemental Figure II

ApoE−−/− ApoE−−/−IL-17A−−/−

plaque area (µm²)
Supplemental Figure III

Panel A: Images showing type I collagen-positive areas in ApoE−/− and ApoE−/−IL-17A−/− models.

Panel B: Bar chart comparing type I collagen-positive area (%). ApoE−/−: 60%, ApoE−/−IL-17A−/−: 50%. The asterisk (*) indicates a significant difference.
Supplemental Figure IV
Supplemental Figure V

A

B

C

Supplemental Figure V