Blood and Marrow Transplantation (BMT)

Philip McCarthy, M.D.
Blood and Marrow Transplant Program
Roswell Park Cancer Institute
2014
CFU-GM
Bone Marrow Product
Mobilization of Stem Cells into the Peripheral Blood

Fig 1. Kinetics of CD34^+ cells (A) and CFU-GM (B) in the peripheral blood of healthy donors treated with G-CSF 5 μg/kg (n = 2) or G-CSF 10 μg/kg (n = 6). Measurements were performed before administration of G-CSF on the corresponding day.

Dreger et al BJH 1994
Types of Transplants

- **Syngeneic**
  - Identical twin

- **Allogeneic**
  - From another person
    - family member (sibling, parent, other relative)
    - unrelated donor

- **Autologous**
  - Self
RPCI BMT Program:

- Autologous up to age 75
- Allogeneic
  - Myeloablative up to age 60
  - Reduced Intensity up to age 75
- Goal: Increasing patient access with decreasing mortality and improved outcome
  - Reduce the toxicity of chemotherapy and radiation therapy
  - Reduce the toxicity of Graft-versus-Host Disease (GvHD) and preserve the Graft-versus-Tumor (GvT) effect
Hematopoietic Stem Cell Transplantation - Classification -

Allogeneic
- HLA-identical sibling or relative

Syngeneic

Autologous

Donor

Conditioning Regimen Intensity
- Non-myeloablative
- Reduced Intensity
- Myeloablative

Graft Source
- Umbilical cord blood
- Bone marrow
- Peripheral blood

Graft manipulation
- Negative or positive selection
- Ex vivo expansion
- In vivo selection

Courtesy M Pasquini, CIBMTR
Autologous BMT

High dose Chemo +/- XRT

Patient

Blood or Marrow Collection

Freezer
Allogeneic BMT

Donor

High dose Chemo +/- XRT

Recipient
HLA (Human Leukocyte Antigens) Inheritance Simplified

Father

- A2
- B7
- DR 01

- A11
- B15
- DR 11

Mother

- A23
- B51
- DR 04

- A30
- B35
- DR 13
He had choose between LIFE or LOVE and DEATH...

JOHN TRAVOLTA

THE BOY IN THE PLASTIC BUBBLE

FROM THE DIRECTOR OF "GREASE"
Bubble Boy (2001)
Location of Centers Participating in the CIBMTR 2013
Transplant Activity in the US

- Autologous
- Related Donor HCT
- Unrelated Donor HCT

*Data incomplete
Indications for Hematopoietic Stem Cell Transplants in the US, 2011

- **Allogeneic** (Total N=7,892)
- **Autologous** (Total N=12,047)

Number of Transplants

- Multiple Myeloma
- NHL
- AML
- ALL
- MDS/MPD
- CML
- Aplastic Anemia
- CLL
- Other Non-Malignant Disease
- Other Cancer
- HD

CIBMTR®
CENTER FOR INTERNATIONAL BLOOD & MARROW TRANSPLANT RESEARCH
Allogeneic Transplants for Age > 20 years, Registered with the CIBMTR

Number of Transplants

<table>
<thead>
<tr>
<th>Year</th>
<th>Related-BM</th>
<th>Related-PB</th>
<th>URD-BM</th>
<th>URD-PB</th>
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<td>2010-11</td>
<td>12500</td>
<td>12500</td>
<td>11000</td>
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</tr>
</tbody>
</table>

by Donor Type and Graft Source
Causes of Death after Autologous Transplants done in 2010-2011

- 69% Primary Disease
- 18% Other
- 8% Infection
- 4% Organ Failure
- 1% Second Malignancy
Causes of Death after HLA-identical Sibling Transplants done in 2010-2011

- Primary Disease: 49%
- GVHD: 17%
- Infection: 12%
- Organ Failure: 15%
- Other: 1%
- Second Malignancy: 5%
Causes of Death after Unrelated Donor Transplants done in 2010-2011

- Primary Disease: 38%
- GVHD: 1%
- Infection: 17%
- Organ Failure: 17%
- Second Malignancy: 19%
- Other: 7%

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Graft-versus-Host Disease (GvHD) and Graft-versus-Tumor (GvT)

- Graft-versus-Host Disease (GvHD) is caused by the immune activation of donor cells recognizing recipient cells as foreign.
- Acute GvHD occurs ~ 100 days after BMT and affects Skin, GI tract and Liver.
- Chronic GvHD occurs after acute GvHD; up to 3 years following BMT.
- GvHD is the most frequent cause of mortality after allogeneic BMT.
- However, GvHD is accompanied by a Graft-versus-Tumor (GvT) effect that can result in eradication of the underlying cancer.
Scylla (GvHD) and Charybdis (Tumor)

MECHANISM OF GVHD

Afferent phase

Ag presentation

Cell activation

Clonal proliferation & differentiation

Lymphokine dysregulation

Efferent phase

Target cell Death

Courtesy of
Mohamed Soliman
RPCI Flow Cytometry

APC

IL-1

IL-2

IL-2R

T

T

T

T

NK

CTL

M

Target cell Death
Probability of Relapse After 2,254 HLA-identical Sibling Transplants for Early Leukemia
One-year Survival by Year of Transplant, Donor and Age, Worldwide

- HLA-matched siblings, Age ≥ 50
- Unrelated donors, Age ≥ 50
- HLA-matched siblings, Age < 50
- Unrelated donors, Age < 50

Acute Leukemia, CML or MDS early disease status.
Transplant regimens

Immunosuppression

Allo Reduced Intensity

Allo Nonmyeloablative

Flu-Cy
Flu-Cy-ATG
Flu-low dose
TBI
Flu ATG

Flu-Mel
Flu-Bu
Flu-Mel-TBI

Auto and Allo Myeloablative

Cy-TBI
Bu-Cy

Regimen Related Toxicity

Later Graft-versus Disease Effect

Relapse

Earlier Anti-Disease Effect

Myelosuppression
Transplant Center-Specific Analysis 2013

• There are 168 Allogeneic BMT Centers reporting to the NMDP.
• There are 13/168 (8%) Allogeneic BMT Centers with survival outcomes that are statistically superior to their expected outcomes
• RPCI is one of these 13 Allogeneic BMT centers
• Data Source: http://marrow.org/Patient/Transplant_Planning/Choosing_a_Transplant_Center/U_S_Transplant_Centers.aspx
Transplant Center Data

• Analysis based on:
  – Unrelated and related donor allogeneic patients 1/1/2009-12/31/2011 with follow-up to 12/31/2012 (3-year rolling average)
  – Analysis only includes centers whose one-year patient status was known for >90% of transplanted recipients

• Essential risk factors include: Diagnosis, Recipient (R)/Donor (D) age, R/D gender, R race, Performance Status (KPS), disease/status, HLA match, conditioning regimen, donor and cell source, co-morbidities, R CMV status, time from diagnosis to BMT, prior autologous BMT

• Baseline and follow-up data were provided to the CIBMTR at the time of transplant (baseline), and at 100 days, six months and annually post-transplant, using standardized forms

RPCI Transplant Center-Specific Survival Analysis 2013 Report (v 04 24 14)
Transplant Center-Specific Analysis

• Number of Patients Transplanted
• Case Mix Score
• Actual 1-year overall survival rate
• Predicted 1-year overall survival rate
• 95% confidence interval (CI) for the predicted 1-year overall survival rate (affected by # of patients transplanted by center, the larger the #, the narrower the CI)
• Results – each transplant center statistically has one of the following:
  – Lower survival rate than predicted (actual survival is <95% CI)
  – Similar survival rate to predicted (actual survival within 95% CI)
  – Higher survival rate than predicted (actual survival is >95% CI)
RPCI BMT Program

• N=159 patients
• Actual 1-year survival rate = 67.3%
• Predicted 1-year survival rate = 59.2%
• 95% CI predicted 1-yr survival rate = 52.2%-66.5%
• Result: RPCI actual 1-year survival is statistically significantly higher than predicted
• For the last 4 years, the RPCI 1 year survival outcomes are higher than predicted
Risk Categories range from 0 (lowest risk) to 5 (highest risk). Analysis prepared by the Center for International Blood and Marrow Transplant Research (CIBMTR) for patients who received a related or unrelated donor BMT (3-year rolling average). The 2013 report analyzes patients transplanted from 2009 to 2011. * Significantly higher survival rate than predicted.
“Around the time he disappeared from his bookstore, Steven was treated for aplastic anemia at UVA,” I said. “I’ve talked with his hematologist. Steven received total lymphoid irradiation, chemotheraphy (sic). Gordon’s marrow was infused into Steven, and Steven then spent time in a laminar flow room…”

All That Remains, Patricia Cornwell, Charles Scribner’s Sons New York, 1992, p 368
Mutational Complexity of Acute Myeloid Leukemia (AML).

Multivariate Risk Classification of Patients with Intermediate-Risk AML.

Revised Risk Stratification of Patients with AML on the Basis of Integrated Genetic Analysis.

Mouse Models of Hematopoietic Stem Cell Transplantation

Dr. M. Nemeth
Dr. E. Repasky
Dr. G Chen
Dr. T Hahn

Dr. X.Cao
Dr. J. Lau

Dr. A. Gudkov
Dr. A. Shakhov
Major Histocompatibility (MHC) Mismatch Model

- Examination of:
  - Graft-versus-Host Disease modulation
    - Robust immune response
    - Faster disease progression
    - Easily reproducible
  - Graft-versus-Leukemia
    - Transgenic mice are in C57BL/6
    - Tumor lines in different H-2 backgrounds

Donor

BALB/c (H2^d^)  C57BL/6 (H2^b^)

Host

Jpegs, Jackson Labs
Preparation of Donor Cells

1. Anti-thy-1.2 mAB & Guinea pig C’ for 45 mins @ 37°C
2. Plastic Petri dish coated with goat α mouse Ab for 1 hr @ 4°C

Adapted from a slide, courtesy of M Capitano
Murine Transplant Simplified

TCD Bone Marrow (1-2 x 10^6 cells) + increasing T cell doses (1-5 x 10^5)
Can we reduce the toxicities of make BMT?

• Can we identify patients at high risk for poor outcome prospectively and
  – modify BMT treatment?
  – intervene earlier in the course of BMT?
A deletion polymorphism in glutathione-S-Transferase Mu (GSTM1) and/or Theta (GSTT1) is associated with an increased risk of toxicity after autologous blood and marrow transplantation

Theresa Hahn, PhD
Evgenia Zhelnova, MD, PhD
Philip McCarthy, MD
Christine Ambrosone, PhD
Lara Sucheston, PhD
Irina Demidova, MD
Valeri Savchenko, MD
Minoo Battiwalla, MD
Shannon Smiley, MD

Funded by American Cancer Society
Roswell Park Alliance Foundation
Collaboration with the National Hematology Research Center in Moscow (not Idaho)
<table>
<thead>
<tr>
<th>Genotype</th>
<th>RR</th>
<th>95% CI</th>
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<tr>
<td>GSTM1</td>
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<tr>
<td>Present</td>
<td>1.0</td>
<td>0.91 - 2.77</td>
<td>NS</td>
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<tr>
<td>Null</td>
<td>1.59</td>
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<tr>
<td>GSTT1</td>
<td></td>
<td></td>
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<tr>
<td>Present</td>
<td>1.0</td>
<td>0.63 – 2.48</td>
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<tr>
<td>Null</td>
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<tr>
<td>GSTM1+/-GSTT1</td>
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<td></td>
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</tr>
<tr>
<td>Both Present</td>
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<td>1.05 – 3.33</td>
<td>0.035</td>
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<td><strong>Allogeneic BMT patients</strong></td>
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<tr>
<td>GSTM1</td>
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<td>Present</td>
<td>1.0</td>
<td>0.64 – 2.89</td>
<td>NS</td>
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<td>Null</td>
<td>1.36</td>
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<td>GSTT1</td>
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<tr>
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<td>GSTM1+/-GSTT1</td>
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<td>Both Present</td>
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<td>0.57 – 2.75</td>
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<tr>
<td>Either/Both Null</td>
<td>1.26</td>
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</tr>
</tbody>
</table>

Genetic susceptibility to Bone Mineral Density (BMD) loss after Auto & Allo BMT

Song Yao, PhD
Theresa Hahn, PhD
Lara Sucheston, PhD
Philip McCarthy, MD
Shannon Smiley, MD
Minoo Battiwalla, MD
Kathy West, PharmD
Dominick Lamonica, MD

Funded by CALGB Young Investigator Award
A delicate balance between bone formation & resorption

Bone loss and risk of fracture

Modified from Khosla & Melton. NEJM 2007;356:2293-2300
Table 2. BMD Change between Baseline and Post-HCT DXA Scans by Autologous and Allogeneic Transplantation*

<table>
<thead>
<tr>
<th>BMD Measures</th>
<th>Autologous HCT</th>
<th>Allogeneic HCT</th>
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<tbody>
<tr>
<td></td>
<td>Spine, Median (IQR)</td>
<td>Spine, Median (IQR)</td>
</tr>
<tr>
<td>BMD loss, adjusted to 100 days (g/cm²)</td>
<td>0.03 (0-0.05)</td>
<td>0.03 (0.01-0.05)</td>
</tr>
<tr>
<td>Annualized rate of BMD loss (%)</td>
<td>7 (0-14)</td>
<td>9 (5-18)</td>
</tr>
<tr>
<td>Ratio of observed/expected annual BMD loss rate (fold)†</td>
<td>37 (3-112)</td>
<td>27 (12-46)</td>
</tr>
<tr>
<td>Years aged by the BMD loss within ~4 months after transplant</td>
<td>10 (1-31)</td>
<td>7 (3-13)</td>
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<tr>
<td></td>
<td>Femur, Median (IQR)</td>
<td>Femur, Median (IQR)</td>
</tr>
<tr>
<td></td>
<td>0.03 (0-0.08)</td>
<td>0.05 (0.04-0.08)</td>
</tr>
<tr>
<td></td>
<td>9 (0-19)</td>
<td>17 (13-27)</td>
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<tr>
<td></td>
<td>60 (2-119)</td>
<td>46 (25-73)</td>
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<tr>
<td></td>
<td>17 (1-33)</td>
<td>13 (7-20)</td>
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</tbody>
</table>

Yao, et al., *BBMT* 2010
Osteoblasts/stromal cells

OPG

RANK

OC precursors

Differentiation, formation

Ca^{2+}

Calcineurin/NFAT

Calcitonin/PTH

Wnt/Lrp5

Vitamin D3

CYP27A1/B1

Mg^{2+}

DBP

Diet

Collagen type I, osteocalcin, alkaline phosphatase, etc

Bone formation

TGF-b, IGF-I

IL-1, IL-6, TNF-a

Bone resorption

Ca^{2+}

M-CSF, G-CSF

CYP19

PGE_{2}

COX-2

Estrogen

PTHR

VDR

PTHrP

VitD3

PTHrP receptor

Calcium

Calcium sensing receptor (CaSR)

CYP24

DBP

Diet

Vitamin D3

CYP27A1/B1

Mg^{2+}

DBP

Diet
Genes and SNPs selected

46 genes and 170 SNPs classified into 6 groups:

- 1. Cytokines and receptors
- 2. Bone matrix proteins and regulators
- 3. Vitamin D receptor / metabolism enzymes
- 4. Estrogen receptor / metabolism enzymes
- 5. PTH & GC
- 6. Miscellaneous

S Yao et al PLOS One 2011
## Genes with SNPs significant in multivariate models of BMD change after BMT

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Auto BMT, Spine</th>
<th>Auto BMT, Femur</th>
<th>Allo BMT, Spine</th>
<th>Allo BMT, Femur</th>
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<td>RANKL-RANK-OPG and regulating cytokines/receptors</td>
<td>None</td>
<td>IL1RN</td>
<td>RANKL *</td>
<td>RANKL *</td>
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<td>Bone matrix proteins and regulating factors</td>
<td>BGLAP</td>
<td>MTHFR, ALOX12</td>
<td>None</td>
<td>COL1A1 *</td>
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<td>Vitamin D receptor and metabolism enzymes</td>
<td>GC, CYP24A1</td>
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<tr>
<td>Steroid hormones/receptors</td>
<td>None</td>
<td>ESR1 *</td>
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Proportion of variance in BMD loss attributed to clinical factors, SNPs and other risk factors

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<tr>
<th>Scenario</th>
<th>Clinical Factors</th>
<th>SNPs</th>
<th>Other Factors</th>
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<tr>
<td>Auto HCT, Spine BMD</td>
<td>10%</td>
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<td>16%</td>
</tr>
<tr>
<td>Auto HCT, Femur BMD</td>
<td>12%</td>
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<td>35%</td>
</tr>
<tr>
<td>Allo HCT, Spine BMD</td>
<td>5%</td>
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<td>30%</td>
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<tr>
<td>Allo HCT, Femur BMD</td>
<td>14%</td>
<td></td>
<td>29%</td>
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</table>
Future Directions

- Preventing BMD loss after BMT is important to prevent risk of fractures and other bone related complications
- >80% of pre-BMT patients are vitamin D insufficient/deficient
- Bisphosphonates require sufficient vitamin D levels and also affect cytokine levels
Genetic susceptibility to unrelated donor hematopoietic cell transplantation-related mortality

NIH (NHLBI) R01 HL107213-01A1
7/5/10-6/30/14

Multiple-PI:
Theresa Hahn, PhD
Dept of Medicine
Lara Sucheston, PhD
Dept of Cancer Prevention & Control
6 Institutions, 12 Investigators

**Institutions:**
- RPCI
- CIBMTR (Center for International BMT Research)
- NMDP (National Marrow Donor Program)
- Univ. Buffalo
- Univ. Chicago
- Univ. Southern California

**Co-Investigators:**
- Philip McCarthy, MD
- David Tritchler, DSc
- Marcelo Pasquini, MD
- Stephen Spellman, MBS
- Song Liu, PhD
- Tom Furlani, PhD
- Ken Onel, MD, PhD
- Chris Haiman, DSc
- Gary Chen, PhD
- David Van Den Berg, PhD
Study population

- 2,800 recipients and their matched donors of 10/10 high-resolution HLA-matched unrelated donor allogeneic BMT from 2000-2008 reported to CIBMTR
- 1,000 recipient/donor pairs from 2009-2011
- Genome Wide Association Study (GWAS) of >1 million SNPs and CNVs
Genetic susceptibility to unrelated donor stem cell transplant-related mortality

- To determine the host and donor genetic contribution to survival (TRM, PFS, OS) after matched unrelated donor BMT
- To determine if the genetic contribution to survival varies by a) conditioning regimen intensity, b) myeloablative conditioning regimen (CyTBI vs BuCy)
- To replicate the top genetic associations in an independent cohort
D-S Stage 1-3, ≤ 70 years
≥ 2 cycles of induction
Attained SD or better
≤ 1 yr from start of therapy
≥ 2 x 10^6 CD34 cells/kg

Stratification based on registration β-2M level and prior thalidomide and lenalidomide use during Induction. Primary Endpoint: powered to determine a prolongation of TTP from 24 months to 33.6 months (9.6 months)
ITT Analysis with a median follow-up from transplant of 34 months p<0.001 Estimated HR=0.48 (95% CI = 0.36 to 0.63), Median TTP: 46 months versus 27 months.

86 of 128 placebo patients not progressing, crossed over to lenalidomide at unblinding in Jan 2010

CALGB 100104, NEJM 2012 follow up to 10/31/2011
CALGB 100104: Overall Survival

ITT Analysis: 35 deaths in the lenalidomide arm and 53 deaths in the placebo arm p=0.028, 3 yr OS 88 vs 80%, HR 0.62 or a 38% reduction in death with the cross over

Median follow-up of 34 months
Immune cell population analysis before and after autoHSCT for MM

- Are there modifiable immune cell populations that correlate with improved outcomes?
- Day +15 absolute lymphocyte recovery (ALC) post-AHSCT correlates with better PFS/OS (Porrata et al Blood 2001)
- Are there immune cell subsets correlating with day +15 ALC recovery (>500 lymphs/µl) and improved PFS/OS?
- 70 multiple myeloma (MM) patients receiving first AHSCT at RPCI from 8/2007 - 9/2012
- Immunophenotyping performed pre- AHSCT (n=70), D+30 (n=40) and D+100 post-AHSCT(n=51)

Day 15 ALC recovery and Immune cell subsets analysis

<table>
<thead>
<tr>
<th>Immune Cell</th>
<th>Pre-BMT</th>
<th>Day 30</th>
<th>Day 100</th>
<th>P</th>
<th>Immune cell associated with faster ALC recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes (n=31)</td>
<td>No (n=20)</td>
<td>Yes (n=25)</td>
<td>No (n=15)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median (range)</td>
<td>Median (range)</td>
<td>Median (range)</td>
<td>Median (range)</td>
<td>P</td>
</tr>
<tr>
<td>Tγδ cells*</td>
<td>2.5 (0-10.3)</td>
<td>0.85 (0.3-5)</td>
<td>1.6 (0.1-9.4)</td>
<td>0.82 (0.2-2)</td>
<td>0.01</td>
</tr>
<tr>
<td>CD8+ Effector cells*</td>
<td>11 (1-45)</td>
<td>4 (0-46)</td>
<td>10 (1-44.2)</td>
<td>5 (0.5-15)</td>
<td>0.01</td>
</tr>
<tr>
<td>CD8+ central memory*</td>
<td>45 (18-78)</td>
<td>58 (29-82)</td>
<td>63 (32.7-83)</td>
<td>75 (58-82)</td>
<td>0.002</td>
</tr>
<tr>
<td>CD8+ central memory*</td>
<td>37 (6-69)</td>
<td>51.5 (20-78)</td>
<td>54 (25-82)</td>
<td>66 (43-90)</td>
<td>0.01</td>
</tr>
<tr>
<td>CD4+25+ T-regs*</td>
<td>29 (4-65)</td>
<td>45 (14-76)</td>
<td>23 (4-76)</td>
<td>37 (12-69)</td>
<td>0.05</td>
</tr>
<tr>
<td>CD4+ Effector cells*</td>
<td>2 (0-18)</td>
<td>0.45 (0-9)</td>
<td>2 (0-33.5)</td>
<td>1 (0-4)</td>
<td>0.03</td>
</tr>
<tr>
<td>CD4+ Thymic emigrants*</td>
<td>36 (2-62)</td>
<td>25 (13-71)</td>
<td>NS</td>
<td>17 (2-38)</td>
<td>8 (2-22)</td>
</tr>
<tr>
<td>NK T-cells</td>
<td>8 (1-33)</td>
<td>4.9 (0-20)</td>
<td>3 (0.6-24)</td>
<td>1.25 (0.1-10)</td>
<td>0.07</td>
</tr>
<tr>
<td>CD8+/CD16+/CD56+*</td>
<td>1.19 (0.27-14.6)</td>
<td>0.72 (0.24-7.95)</td>
<td>1.24 (0.29-2.31)</td>
<td>0.67 (0.39-2.25)</td>
<td>0.06</td>
</tr>
<tr>
<td>Absolute T-cell count</td>
<td>37 (3-72)</td>
<td>29 (0-61)</td>
<td>12 (4-43)</td>
<td>6 (0.8-22)</td>
<td>0.03</td>
</tr>
<tr>
<td>CD8+ naïve T cells*</td>
<td>32 (15-60)</td>
<td>35 (19-66)</td>
<td>NS</td>
<td>52 (35-75)</td>
<td>67 (37-83)</td>
</tr>
<tr>
<td>CD4-CD8- T cells*</td>
<td>1.4 (0.4-5)</td>
<td>1.4 (0.6-6)</td>
<td>NS</td>
<td>1.4 (0.3-5.3)</td>
<td>0.8 (0.2-3)</td>
</tr>
<tr>
<td>Absolute Basophil count</td>
<td>0.03 (0.01-0.13)</td>
<td>0.03 (0.01-0.14)</td>
<td>NS</td>
<td>0.03 (0.01-0.11)</td>
<td>0.03</td>
</tr>
<tr>
<td>Absolute B-cell count</td>
<td>0.05 (0.01-4.77)</td>
<td>0.03 (0.01-0.59)</td>
<td>NS</td>
<td>0 (0-2.26)</td>
<td>0 (0-0.01)</td>
</tr>
</tbody>
</table>

*Percent of Total T cell count

Other immune cells in the panel were compared, but were not significantly different at any time interval.

Yellow: P=0.001-0.002; Orange: P=0.01; Green: P=0.02-0.05; Blue: P=0.06-0.09
Higher T $\gamma\delta$ and CD8+ effector cells correlate with improved PFS and OS.
BMT CTN 0702: SCHEMA

Register and Randomize → MEL 200mg/m² → VRD x 4* → Lenalidomide Maintenance**

* Bortezomib 1.3mg /m² days 1, 4, 8, 11
Lenalidomide 15mg days 1-15
Dexamethasone 40mg days 1, 8, 15

** Lenalidomide 10 mg daily x 3mo then 15 mg daily. Total duration of maintenance 3 years

Courtesy of M. Pasquini
Disease Response in PRIMeR Study

Arrows indicate time points for disease assessment for immunophenotyping BM samples for the PRIMeR Study.
People and Services who make the BMT program possible

- George Chen
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- Surgery Svc
- Pathology Svc
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